HORIZON™
Modular Infusion System

Service Manual

McGaw, Inc.
July 1994
950323 Rev B

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Manual Revision Record

DATE	REV.LTR.	DESCRIPTION OF REVISION
12/92	A	Original Issue
7/94	B	PCB layout changes, Improved Troubleshooting Guide, Expanded Part Replacement List, New Software Revision

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WARNINGS AND CAUTIONS

WARNING: **Shock Hazard.** USE A LINE ISOLATION TRANSFORMER AND CAUTION WHENEVER WORKING ON THE HORIZON™ PUMP WITH THE CASE TOP REMOVED. FAILURE TO DO SO COULD RESULT IN BODILY HARM.

- Prior to disassembling or preforming service on the Horizon™ Pump it is recommended that the pump be disconnected from the AC power source unless you feel it is specifically required for a particular test. If you find it necessary to have the device connected to an AC power source use a line isolation transformer and caution. Failure to do so could result in bodily harm.

- The inside of the Horizon™ case has a conductive coating which is connected to ground through the power supply module. When servicing the Horizon use caution to prevent accidental shorting to this coating.

- A large portion of the Horizon power supply board is connected *directly* to the AC Line and contains *high voltages*.

- To avoid electrical shock, turn off the pump and disconnect it from the electrical outlet before cleaning.

- The ground reference shown in the primary or high voltage side of the 16 volt supply is not the same as circuit ground throughout the rest of the pump, and it is different from earth ground.

WARNING: Do not perform service procedures and/or tests while the Horizon™ is in patient vicinity or while in patient use. Failure to comply could result in bodily harm.

WARNING: If the product is partially or completely disassembled, or a component or assembly has been replaced or repaired, the unit must undergo and pass all performance checks outlined in section 7.4 of this manual and the appropriate calibrations and or tests outlined in section 7.7 prior to use for patient care. The Horizon sets are guaranteed to maintain all specified accuracy claims for 72 hours of patient use. All final performance testing and calibration of the Horizon pump must be performed with a set that is acceptable for patient use with an exception for set sterility only. Failure to do so may cause bodily harm and will void all warranties.

CAUTION: To avoid mechanical or electronic damage, do not steam autoclave or immerse the pump in any fluids or cleaning solutions.

CAUTION: To avoid mechanical damage, DO NOT use acetone, solutions containing glutaraldehyde, ammonium chlorides or abrasive cleaners on the instrument.

CAUTION: Sterilization of the pump using ethylene oxide (EtO) gas or Autoclaving is not recommended.

CAUTION: Rework of multi-layer boards should not be attempted unless personnel have attended and passed an accredited course in soldering techniques for this type of board and express written consent has been obtained from an authorized McGaw Representative. Failure to do so will void all warranties.

CAUTION: Individual component replacement is *not* recommended and will void any and all warranties unless express written consent has been obtained from an authorized McGaw Representative. McGaw recommends board replacement as it may not be possible to test complete circuit function to factory specifications.

CAUTION: If you will be working on the main board with the EPROMs removed, it is **strongly** recommended that you disconnect both motors from the mechanism interface board **prior** to powering up. Otherwise, the ASIC can power up with one or more of the motor windings permanently enabled, and cause them to overheat. The motors can be disconnected at J6 and J9 on the Mechanism Interface PCB.

CAUTION: The backlight voltage passes from the display board, through the LCD controller board, and to the LCD display module. If this connection is broken and the inverter is on, it will emit a high frequency audible noise, and can be damaged by operating this way for any length of time.

CAUTION: Continuous deep discharge of the battery may cause damage to battery cells and lead to premature battery replacement.

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1 INTRODUCTION

1.1 Disclaimer

Due to the criticality of product performance, McGaw, Inc. recommends that all required service on this product be performed only by an authorized McGaw, Inc. Service Center or a qualified biomedical repair professional who has attended the McGaw service training course. Repairs should not be attempted without a current Service Manual. Repairs should not be attempted by other than qualified personnel that are knowledgeable in the areas of microprocessor controlled electronics, digital and analog circuitry, electromechanical devices, testing, static control and soldering techniques. Repairs should not be attempted which have not specifically been identified in this Service Manual.

WARNING: If the product is partially or completely disassembled, or a component or assembly has been replaced or repaired, the unit must undergo and pass all performance checks outlined in section 7.4 of this manual and the appropriate calibrations and or tests outlined in section 7.9 prior to use for patient care. The Horizon™ sets are guaranteed to maintain all specified accuracy claims for 72 hours of patient use. All final performance testing and calibration of the Horizon pump must be performed with a set that is acceptable for patient use with an exception for set sterility only. Failure to do so may cause bodily harm and will void all warranties.

CAUTION: Rework of multi-layer boards should not be attempted unless personnel have attended and passed an accredited course in soldering techniques for this type of board and expressed written consent has been obtained from an authorized McGaw Representative. Failure to do so will void all warranties.

CAUTION: Individual component replacement is not recommended and will void any and all warranties unless express written consent has been obtained from an authorized McGaw Representative. McGaw recommends board replacement as it may not be possible to test complete circuit function to factory specifications.

By performing any repairs with or without use of this manual as reference, you hereby acknowledge and agree that McGaw and its distributors shall be indemnified and held harmless from and against any and all damages, liabilities, actions or causes of action, including attorney's fees, directly or indirectly arising out of or resulting from such repairs.

You also understand that neither McGaw nor its distributors shall be liable for any incidental or consequential loss, damage, or expense directly or indirectly arising from authorized or

unauthorized repair of this device since the quality of repair, and the knowledge and experience of personnel performing repairs, as well as other factors relating to matters beyond McGaw's control, directly affect the device and the results obtained from its use.

McGaw neither assumes, nor authorizes any other person to assume for it, any other or additional liability or responsibility in connection with repair of this device.

The information contained in this manual is current as of the date of issue.

1.2 Warranty

McGaw, Inc. hereby warrants that reasonable care has been used in the manufacture of each Horizon™ Infusion Pump. When properly used and maintained it shall be free from defects in material and workmanship for a period of one year after the date of shipment. Any Horizon™ Infusion Pump that is found not to meet these standards within this one year period will be repaired after examination by McGaw, or, at McGaw's option, will be replaced without charge. If the defect has been caused by misuse, unauthorized modification, or abnormal conditions of operation, repairs will be billed at McGaw's then current charges. In this case, an estimate will be submitted before work is started, if requested. The defective device should be returned to McGaw, properly packaged, postage prepaid. Loss or damage in return shipment to McGaw will be at the purchaser's risk. The foregoing express warranty, as conditioned and limited, is in lieu of and excludes all other warranties not expressly set forth herein, whether expressed or implied by operation of law or otherwise including, but not limited to, any implied warranties of merchantability or fitness, since handling, storage, and cleaning of these devices, as well as factors relating to other matters beyond McGaw's control, directly affect these devices and the results obtained from their use. McGaw shall not be liable for any incidental or consequential loss, damage or expense, directly or indirectly arising from the use of this device other than replacement of all or part of it. McGaw neither assumes, nor authorizes any other person to assume for it, another or additional liability or responsibility in connection with this device.

This warranty will not apply to any Horizon Infusion Pump or component thereof which has been:

1) Repaired by anyone other than authorized McGaw trained technician or repair facility;
2) Altered in any way that, in McGaw's judgement, affects its stability or reliability;
3) Subjected to misuse, negligent handling, or accident;
4) Used in any manner not according to the instructions furnished by McGaw in the Operation Manual and/or Service Manual.

This warranty extends only to the first purchaser or lessee and does not extend to, and may not be enforced by, any other person.

1.3 Intended Use, Service Manual

This manual is intended to be used by a qualified biomedical service professional for the troubleshooting and repair of the referenced equipment. Repair of the device should only be performed by a qualified biomedical service professional. Although it is not mandatory that each service professional be certified by McGaw, Inc. prior to servicing the Horizon™ Pump, it is recommended, and will be made available to your institution upon the expiration of the standard Horizon Pump warranty. Please contact Customer Service (see Chapter 9) for additional information on the training classes and fee structure.

NOTICE: This manual contains information and data proprietary to McGaw, Inc. This information is provided solely for technical personnel in maintaining and servicing the Horizon™ Infusion Pump. None of the information contained herein may be duplicated or used in any manner other than for the maintenance and servicing of the pumps or their component parts. Any unauthorized use of the information contained herein may subject the user to substantial liability for infringement of trade secrets, copyright, and patents.

This Service Manual is organized into nine chapters as outlined in the Table of Contents. A Horizon Operation Manual is included at the end of this manual for easy reference. Please refer to Chapter one of the OPERATION MANUAL for the intended use of this infusion pump.

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2 DESCRIPTION

2.1 Visual Indicators and Controls

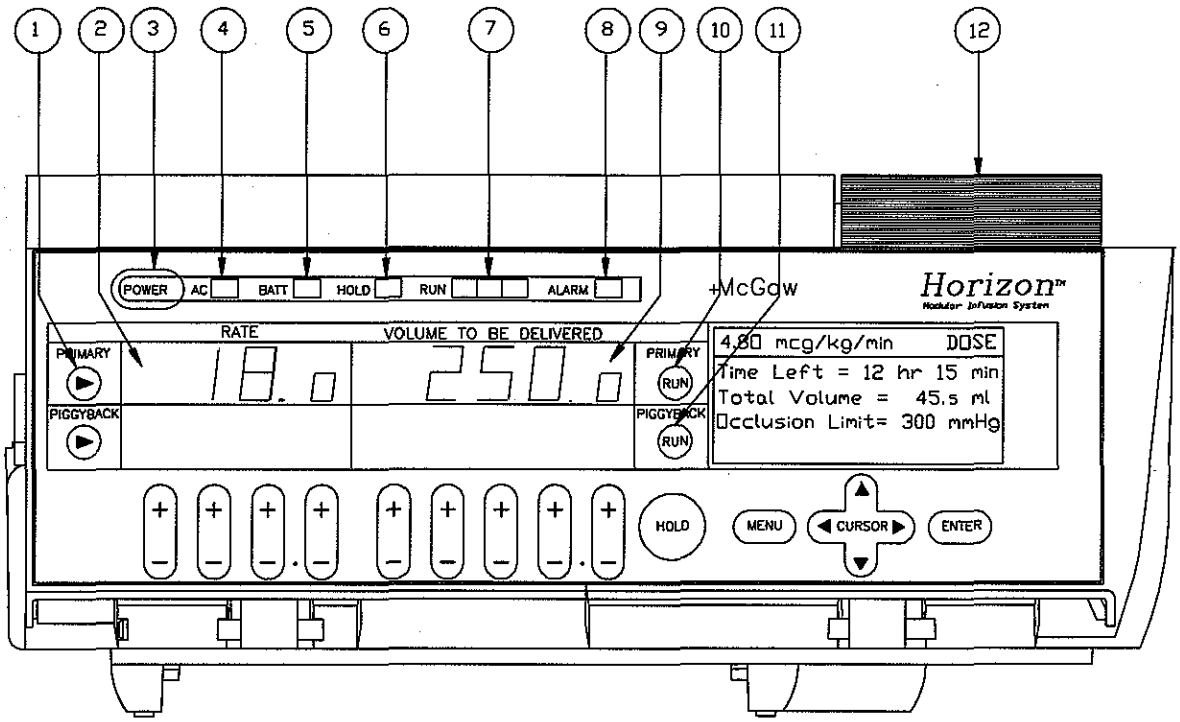

Figure 2-1: Front View

1. PRIMARY INDICATOR Key
2. Primary Rate Display
3. POWER Key
4. AC Use Indicator
5. Battery Use Indicator
6. Hold Indicator
7. Run Indicator
8. Alarm Indicator
9. Primary Volume Display
10. PRIMARY RUN Key
11. PIGGYBACK RUN Key
12. Door Lever

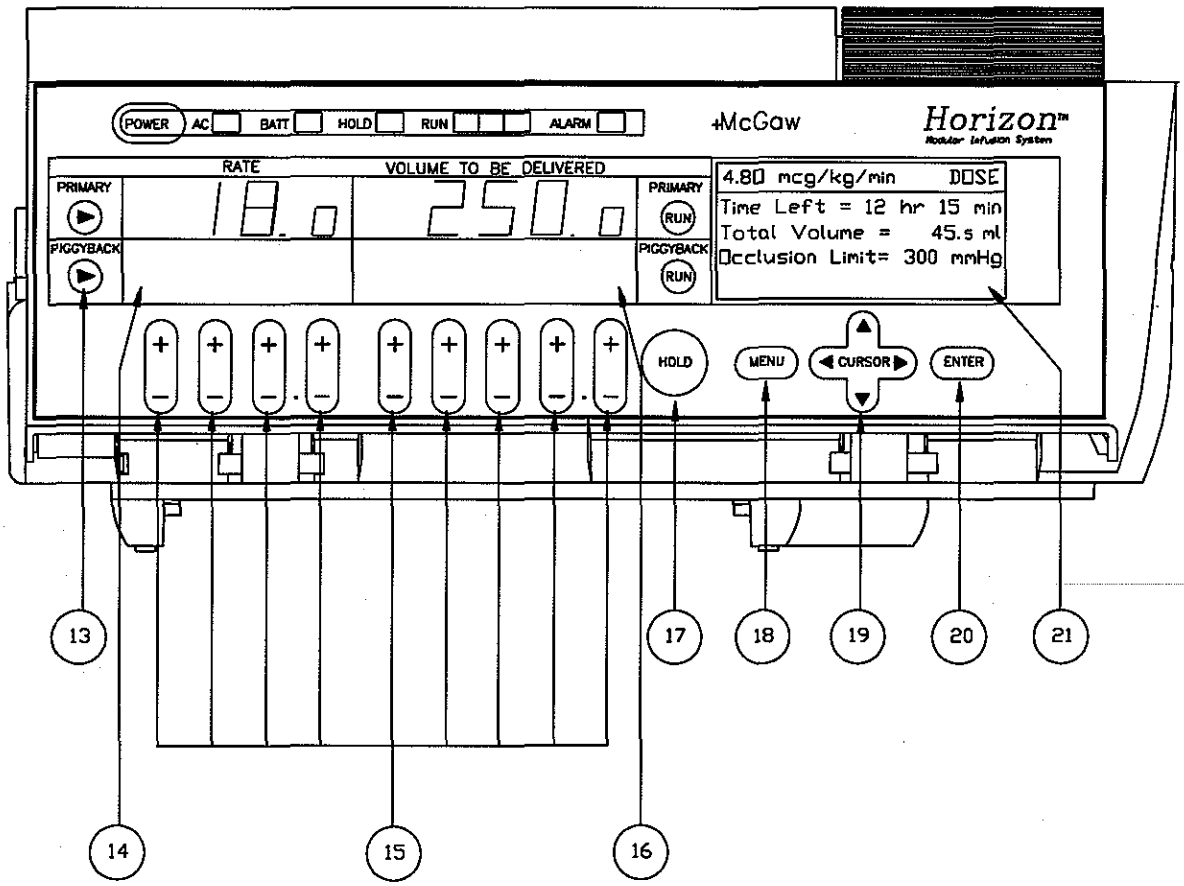

Figure 2-2: Front View

13. PIGGYBACK INDICATOR Key
14. Piggyback Rate Display
15. DATA Keys
16. Piggyback Volume Display
17. HOLD Key
18. MENU Key
19. CURSOR Keys
20. ENTER Key
21. Information (LCD) Display

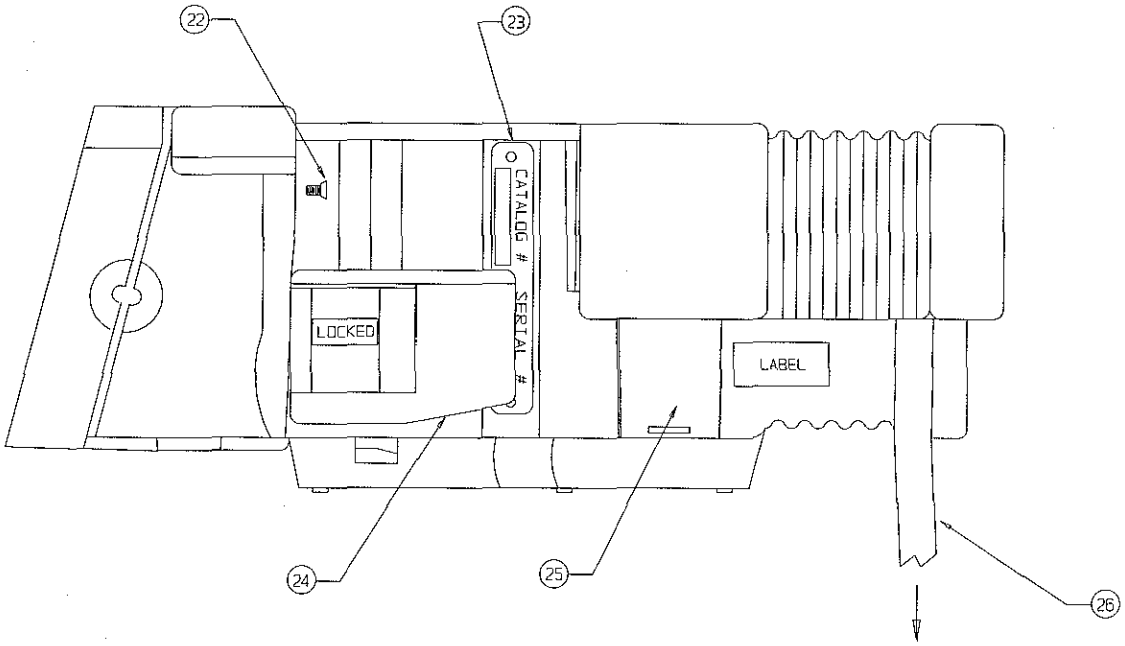

Figure 2-3: Right View

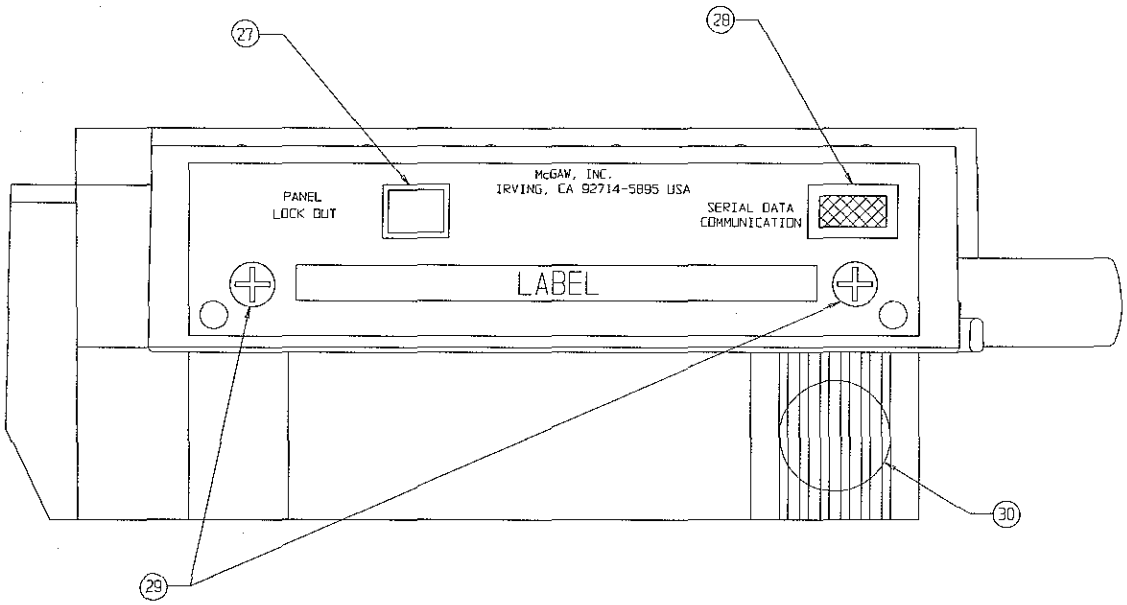

Figure 2-4: Rear View

22. Phillips Head Case Top Screw
23. Catalog and S/N Identification
24. QuickClamp™
25. Daisy Chain Outlet Door
26. AC Power Cord
27. Panel Lock-Out Switch
28. Serial Data Communication Port
29. Quarter-turn Case Top Screws
30. Main Speaker

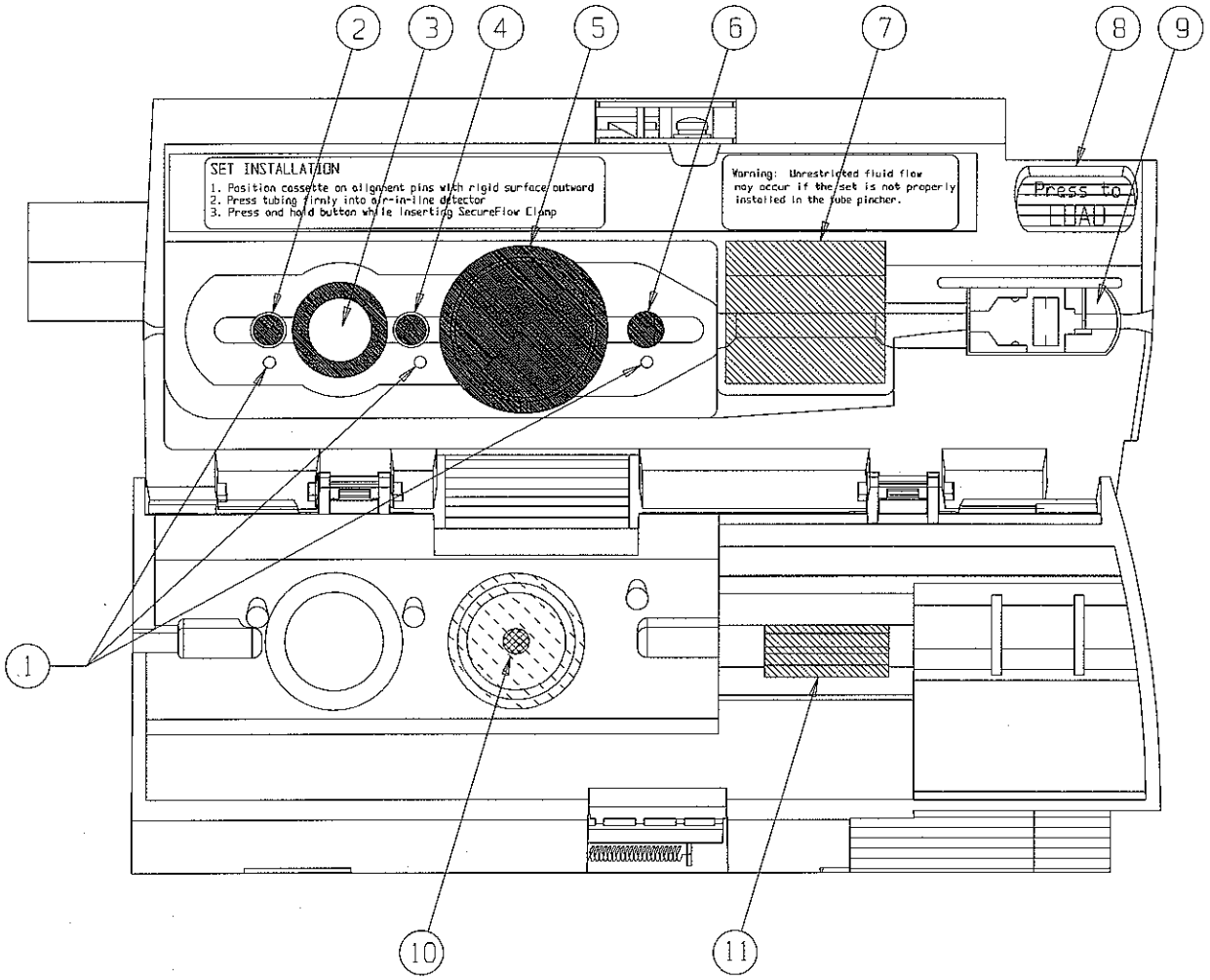

Figure 2-5: Front View, Door Open

1. Cassette Alignment Pins
2. Inlet Valve
3. Refill Piston
4. Transfer Valve
5. Petal Module Cover
6. Restriction/Outlet Valve
7. Air-In-Line detector
8. Set Loading Button
9. Anti-Freeflow Socket
10. Pressure Transducer cover
11. Tube Pusher

2.2 Specifications

Mechanism:	Volumetric (Non Drop-Counting), Positive Pressure Displacement Reservoir
Dimensions:	Width 12.4" (31.5 cm) Height 4.8" (12.2 cm) Depth 12.2" (31.0 cm)
Weight:	Approximately 11.9 lbs (5.4 kg)
Power Requirements:	90-132 VAC, 30 Watts, 47/63 Hz excluding accessories (domestic), 180-264 VAC, 30 Watts, 47/63 Hz excluding accessories (international)
Grounding Resistance:	Meets UL Standard 544
Leakage Current:	Meets or exceeds UL Standard 544, Section 27.2, and ANSI/AAMI Safe Current Limits (July 9, 1985) for each device.
Plug:	Hospital Grade (3 pin)
Pole Size Range:	0.75" to 1.25"
Battery:	12 Volt sealed lead-acid battery for ambulatory use. Run time is dependent on the state of battery charge and the rate of fluid delivery.
Rate Range:	Standard: (Primary and Piggyback) 0.1 to 999.9 ml/hr Micro: (Primary and Piggyback) 0.1 to 99.9 ml/hr
Keep Open Rate:	3 ml/hr for prescribed delivery rates of 3 to 999.9 ml/hr, or the continuation of the prescribed delivery rate for 0.1 to 2.9 ml/hr settings
Volume to be Infused:	0.1 to 9999.9 ml
Volume Delivered:	Volume Delivered Accuracy is ±5%

Fluid Types:	All standard I.V. fluids, including lipids & TPN
Occlusion Pressure:	75, 100, 200, 300, 400, 500 and 750 mmHg. Standard Mode default is 300 mmHg. Micro Mode default is 100 mmHg. Both defaults are user adjustable.
Alarms:	Air-In-Line, Battery Very Low, Container Empty, Door Open, Downstream Occlusion, Hold Time Exceeded, Repair Instrument, Set Improperly Loaded, Set Piggyback Rate, Set Piggyback Volume, Set Primary Rate, Set Primary Volume, System Alarm, Upstream Occlusion
Air-In-Line Alarm:	0.09 cc
Hold Time Exceeded:	Activated after three minutes without user interaction (deactivated if the door of the pump is open)
Memory:	Permanent data retention after the pump is turned off, unless the Data Retention Defaults have been otherwise selected in the Biomed Options.

3 RECOMMENDED RECEIVING PROCEDURE

3.1 Receiving Notices

WARNING: If the product is partially or completely disassembled, or a component or assembly has been replaced or repaired, the unit must undergo and pass all performance checks outlined in section 7.4 of this manual and the appropriate calibrations and or tests outlined in section 7.9 prior to use for patient care. The Horizon™ sets are guaranteed to maintain all specified accuracy claims for 72 hours of patient use. All final performance testing and calibration of the Horizon must be performed with a set that is acceptable for patient use with an exception for set sterility only. Failure to do so may cause bodily harm and will void all warranties.

3.1.1 Damaged Goods

Upon receipt, count and inspect your freight before the carrier departs. Damaged merchandise should not be accepted. Identify any items that are damaged or lost, and have the extent of the damage or loss noted on the customer's copy of the delivery document by an agent of the transportation company. If damage is discovered after receipt of shipment, notify the transportation company immediately, and request that inspection be made and inspection report rendered. McGaw will be happy to issue a credit for the loss or damage, and file a claim with the carrier, providing your request and the carrier's freight bill indicating the item and quantity damaged or not received are promptly forwarded to the Carrollton, Texas office (see Chapter 9), and received within ten days. The claim request must be accompanied by a delivery receipt or an inspection report upon which the transportation company has properly noted such damage or loss.

3.1.2 Goods Received in Error

Items ordered or shipped in error, may be returned to the warehouse provided Customer Service is notified (see Chapter 9), and the products are returned within 14 days. Items ordered in error must be returned freight prepaid by the customer.

Credit will be issued for all returns for goods received in error provided:
a. Proper authorization has been obtained (see Chapter 9).
b. Products are in the original undamaged cases, suitable for immediate resale.
c. Products are current inventory items.
d. Merchandise has been shipped and billed to the customer by McGaw.

Certain products are not eligible for return for credit. These are:
a. Products which have been used.
b. Products whose labels or seals have been tampered with or removed.

Except in the case of a McGaw error, items must be returned freight prepaid by the customer.

3.1.3 Late Shipments

McGaw shall be excused from any delay in, or impossibility of performance due to any cause beyond its or its suppliers' or subcontractors' control, including, but not limited to: acts of God, war, acts of government, acts of purchase priorities or allocations, raw material shortages, fire, flood, strike, labor trouble, sabotage or delay in obtaining labor, materials, equipment, or transportation.

3.1.4 Expedited Shipments

When expedited transportation, specialized services, or alternate transportation modes are specified by the customer, an additional charge to cover the premium expense will be added to the invoice.

3.1.5 Receiving Inspection

Each Horizon™ Infusion Pump is factory tested and inspected prior to its final packaging and shipment. There is, however, the possibility of in-transit damage which may or may not be obvious; therefore, the following inspection is recommended. If functional testing is required upon receipt by your (customer) policy, refer to the section in this chapter titled "Check-in Procedure."

1. Before opening the shipping container, inspect it carefully to assure the absence of obvious damage. If damage is present, notify the freight carrier immediately, and wait to open the container until a representative of the shipping company is present. (It is difficult to place responsibility for shipping damage after the shipping container is opened). Do not return damaged equipment to the manufacturer unless specifically authorized to do so by the company, whether or not the company is responsible for the repair.
2. Remove the pump from the shipping carton.
3. Carefully inspect the pump for dents, scratches, missing parts, or any other obvious signs of shipping damage.
4. Make sure the door of the pump opens and closes easily, without binding, and that it is properly aligned with the bezel.

5. Make sure there are no visible dents, tears or scratches on the pump membrane panel.
6. Check the QuickClamp™ for ease of operation.
7. Inspect the power cord for nicks or cuts, and the plug for bent or insecure prongs.
8. Make sure the petal cover, valve tips and pressure transducer cover are not torn or otherwise damaged.

3.2 Check-In Procedure

Prior to use, it is recommended that the pump be checked-in according to sections 3.3 through 3.8 of this manual. If the pump fails to operate, contact McGaw, Inc. for a Returned Goods Authorization Number (RGA#). See Chapter 9 for information on contacting the company.

Each pump has been inspected and tested prior to shipment; however, in-transit handling or repair work may have caused some misalignment. Therefore, the procedures outlined in this chapter are intended to be used by qualified service personnel in the initial and routine checks of the Horizon™ Infusion Pump.

3.3 Mechanical Inspection

3.3.1 Door Alignment Inspection

1. Make sure the door of the pump opens and closes easily, without binding, and that it is properly aligned with the bezel. The door latch allows the door to close completely.
2. The gap on each side and along the top of the door is symmetrical.

3.3.2 Switch Inspection

1. Push the POWER Key to turn the pump on.
2. Push the POWER Key again to turn the pump off.
3. Make sure there are no visible dents, tears, scratches or cracks on the pump membrane panel.

3.3.3 QuickClamp™ Inspection

1. With the QuickClamp™ in the unlocked position it will slide easily up and down with a spring action return to the narrow pole position.

2. Rotate the QuickClamp lever counterclockwise to make sure the locking mechanism is intact.

3.3.4 Gasket and Hardware Inspection

1. All gaskets and seals are securely attached.
2. Petal cover and valve tips are in place and in good condition.
3. The cover on the pressure transducer shall not have any rips, tears, punctures or indentation marks.
4. All screws are tight and secure.
5. No cracks in the bezel or inner door face are present.
6. Tube pusher is intact and securely mounted.
7. No cracks in the case or handle exist.
8. Inspect the power cord for nicks or cuts. Inspect the plug for bent or insecure prongs.

3.4 Main Battery Check and Charging

All rechargeable batteries automatically discharge when not in use. The rechargeable battery used in this pump is no exception. Therefore, it is suggested that before attempting to use the pump for the first time, the battery be fully charged by connecting the power cord of the pump to a hospital grade electrical outlet. Allow at least 24 hours to fully charge the battery from a fully discharged condition. In order to maintain the battery in a fully charged condition, the pump should be plugged into a hospital grade electrical outlet whenever possible. To check the level of the battery charge refer to the section in Chapter 4 of the Operation Manual titled "Check Battery Level." When charging multiple devices in a storage facility, ***not in the vicinity of patients***, 12 Horizons may be daisy-chained together for outlet conservation purposes.

3.5 Default Software Settings

1. Set all defaults according to your individual institution's needs. Refer to Chapter 6 in the Horizon™ Operation Manual for instructions on performing these operations.
2. Verify the pump's calendar and clock are set appropriately. Refer to Chapter 6 "Review Time and Date" in the Operation Manual for instructions.

Table 3-1: Default Software Settings

Description	Factory	This Institution
Piggyback/Primary Volummes To Be Delivered	0.0	
Total Volume	0.0	
Occlusion Limit	300 mmHg	
Alarm Intensity	HIGH	
Default Occlusion Limit Fixed Value =	 300 mmHg	
Data Retention Defaults	Retain All	
Control Special Modes: Allow PROFILE Allow PROGRAM	 N N	
Control Special Features: Allow TIME & VOLUME Allow PIGGYBACK Allow MAX PRESSURE Allow SYRINGE (max rate limited to 300 ml/hr.) Allow RUN SCHEDULE	 N Y N N N	
MICRO Status (max rate limited to 99.9 ml/hr)	OFF	
Audible Signal Options: Key Clicks Channel Transitions Hold Reminder Occlusion Warning	 Y N N N	

Note: If a feature is not listed, then its default setting may vary upon leaving the factory. For a detailed description of each item please refer to the respective section in Chapter 6 of the Operation Manual.

3.6 Simulated Use and Performance Check

Equipment Required

1. Horizon™ I.V. Fluid Delivery Set
2. I.V. Container with suitable fluid in it
3. Needle and Syringe, 3 ml
4. IV pole or equivalent
5. AC power source

Test Procedure: Simulated Use

This section was written to match the pump as it comes from the factory. It is also written to match **software revision level: MP-H, PP-L, DP-A or B.** If the device being tested has been operated or used in any way or the software revision in the device has changed, those observations listed in the Observation column may not match the device. The table can still be used for verifying the pump's operations with the understanding that your default settings and other values may differ from that listed below.

Please refer to Chapter 3 in the Operation Manual for operating instructions.

Table 3-2: Simulated Use Initial Checkout

Action	Observation
1. Unlock the QuickClamp™ by rotating the QuickClamp lever clockwise one quarter turn. Attach the pump to an I.V. pole by pressing down on the unlocked QuickClamp lever. While holding the lever down, position the pump such that the pole is seated in the V-block of the instrument case. Release the QuickClamp. With the pump now supported by the I.V. pole, use one hand to lightly lift the pump's handle. Use your free hand to snug the QuickClamp fit by squeezing together the top of the pump and the bottom portion of the unlocked lever. Rotate the QuickClamp lever 1/4 turn counterclockwise to lock the QuickClamp.	1. Verify that the QuickClamp mechanism tightens firmly onto the pole. **Note:** As the open QuickClamp lever is snugged tighter, the pump will become more securely mounted on the I.V. pole.
2. Press the POWER Key to turn on the pump.	2. The speaker will sound a tone. The BATT and HOLD LEDs will illuminate. The RATE and VOLUME TO BE DELIVERED columns will display values, the LCD will illuminate and display; Load the Set and then close the Door. Total Volume = xxxx.x ml Occlusion Limit = 300 mmHg **Note:** If no keys have been pressed for approximately 30 sec, "HOLd" will be displayed in the PRIMARY or PIGGYBACK channel, whichever is not active. If no keys have been pressed for 3 min., "HOLd" will flash in the PRIMARY volume to be delivered column of the LED's and the alarm will sound.

Action	Observation
3. Individually press and hold the + and - portion of each DATA Key for one full cycle (0,1,2,...,9,0). Press the PIGGYBACK INDICATOR Key and repeat. Return the PIGGYBACK rate and volume to be delivered values to zero.	3. Key clicks are heard as the LEDs sequence through numbers 0 - 9 with carry over displaying the number 10 after cycling past the number 9. No LED segments are absent from the number 8. An audible tone will sound as the hundreds column of the RATE and the thousands column of the VOLUME TO BE INFUSED, are advanced past 9 or if any column is decremented past 0. This same tone will sound if an attempt is made to set the rate or volume less than 0.0. **Note:** Whichever key is depressed, PRIMARY INDICATOR or PIGGYBACK INDICATOR, the respective display will illuminate brighter, while the other display becomes dimmer.
4. Enter a primary rate of 220 and a primary volume of 2. Press the PRIMARY RUN Key.	4. The audible alarm will begin to sound and repeat approximately once every three seconds. The ALARM LED will illuminate. The LEDs in the primary volume to be delivered column will flash "SEE HELP". The LCD will display; CLOSE ROLLER CLAMP Then open door. Press LOAD and reload Secure Flow Clamp ...(picture)...

Action	Observation
5. Press the MENU Key.	5. The alarm silences. The HOLD LED illuminates. The LED's will display a primary rate of 220 and a volume to be delivered of 2. The LCD displays; CLOSE ROLLER CLAMP Then open door. Press LOAD and reload Secure Flow Clamp Picture...
6. Press the HOLD Key.	6. The LCD will display; Load the Set and then close the Door. Total Volume = (some value)ml Occlusion Limit = 300 mmHg Flow Clamp Position HELP
7. Press the MENU Key	7. The LCD will display; USER MENU Clear Total Volume Occlusion Limit 300 mmHg DOSE Mode Setup Pump Pause
8. Press the ENTER Key.	8. The LCD will display; The present Total Volume of (some value)ml will be zeroed. Is this OK? YES NO Cursor ⟷ & Press ENTER

Action	Observation
9. Press the ENTER Key.	9. The LCD will display; Load the Set and then close the Door. Total Volume = 0.0 ml Occlusion Limit = 300 mmHg Flow Clamp Position HELP
10. Press the MENU Key.	10. The LCD will display; USER MENU Clear Total Volume Occlusion Limit 300 mmHg DOSE Mode Setup Pump Pause
11. Press the down arrow CURSOR Key until "Check Battery Level" is highlighted. Press the ENTER Key.	11. The LCD will display; Check Battery Level DISCHARGING EXIT This means the battery is discharging/operating on battery power.
12. Plug the power cord into an AC outlet.	12. After approximately 1-2 sec. the BATT LED will extinguish. The AC LED will illuminate. The LCD will display a bar graph. An indication of FULLY CHARGED means the battery is approximately 95% or more, charged. An indication of CHARGING means the battery is less than approximately 95% charged.
13. Press the ENTER Key. Then press the MENU Key followed by the down arrow CURSOR Key until "Set LCD Contrast" is highlighted. Press the ENTER Key.	13. The LCD will display; EXIT Adjust cursor ⟷ until this message is clear. Then press Enter Key.

Action	Observation
14. Cursor left and right.	14. The contrast changes from high to low and back to high again. The backlight intensity should be present and not erratic or flickering.
15. Press the ENTER Key.	15. The LCD will display; Load the Set and then close the Door. Total Volume = 0.0 ml Occlusion Limit = 300 mmHg Flow Clamp Position HELP
16. Open the door.	16. The only display change will occur after several seconds, after which the PIGGYBACK LEDs will display "HOLd". Opening the door disables the HOLD time alarm.
17. Spike the fluid container with the I.V. set, and prime the set with fluid. Make sure all air is removed from the set before closing the roller clamp. Load the cassette into the pump mechanism according to the instruction label inside the door. Close the door.	17. The RATE and VOLUME TO BE DELIVERED columns will display those values that were present prior to opening the door. The LCD will illuminate and display; Set the Rate & Volume. Then Press RUN Total Volume = 0.0 ml Occlusion Limit = 300 mmHg Flow Clamp Position HELP
18. Press the HOLD Key. Press the PIGGYBACK Indicator Key and enter a piggyback rate and volume of 0.0.	18. The LCD will not change. The row of PIGGYBACK LEDs will illuminate. The row of PRIMARY LEDs will become dim.

Action	Observation
19. Press the PRIMARY INDICATOR Key and enter a primary rate of 120, and a primary volume of 2. Open the roller clamp. Press the PRIMARY RUN Key.	19. The row of PIGGYBACK LEDs will extinguish and the row of PRIMARY LEDs will illuminate. The cassette chambers will be filled and pressurized. The HOLD LED will extinguish and the RUN LEDs will light in a sequential fashion. The Tube Pincher will click open. The LCD will display; Time Left = 0 hr 1 min Total Volume = 0.0 ml Occlusion Limit = 300 mmHg
20. Press the PIGGYBACK INDICATOR Key.	20. The Piggyback display will illuminate showing both rate and volume to be infused values. The display will cease to illuminate within 5 seconds of releasing the PIGGYBACK INDICATOR Key. **Note:** The piggyback function is disabled when the device is in any mode **other** than STANDARD MODE.
21. Wait until the infusion is complete.	21. An alarm sounds, indicating a KVO state of operation. The primary rate will be 3.0 ml/hr and the volume to be delivered will be 0.0, each will be flashing. The LCD will display; KVO: PRIMARY COMPLETE Total Volume = 2.00 ml Occlusion Limit = 300 mmHg

Action	Observation
22. Press the HOLD Key.	22. The alarm will silence. The HOLD LED will illuminate. The RUN LEDs will extinguish. The primary RATE will display 120 and a Volume to be delivered of 0.0. The LCD will display; PRIMARY COMPLETE Time Left = 0 hr 0 min Total Volume = 2.0 ml Occlusion Limit = 300 mmHg
23. Enter a new primary rate of 90 ml/hr and a volume of 2.0. Press the PRIMARY RUN Key.	23. The LCD wil display: Time Left = 0 hr 0 min Total Volume = 2.0 ml Occlusion Limit = 300 mmHg
24. Close the clamp downstream from the cassette.	24. The "Total Volume =" value should stop increasing, for a complete occlusion, and approximately 25 seconds later an audible alarm should sound associated with a flashing LED message of "OCCL". **Note:** The amount of time will vary depending upon how far downstream the clamp is, the occlusion limit setting as well as the infusion rate.

Action	Observation
25. Press the HOLD Key and open the downstream clamp. Inject an air bubble of at least 0.5 ml into the "Y" site of the tubing on the upstream side of the pump. Enter a primary rate of 900 ml/hr and a volume to be infused of 20 ml. Press the PRIMARY RUN Key.	25. The cassette chambers will be filled and pressurized. The Tube Pincher will click open. The HOLD LED will extinguish. The RUN LEDs will begin to illuminate sequentially. The LCD will display; Time Left = 0 hr 1 min Total Volume = 2.0 ml Occlusion Limit = 400 mmHg **Note:** The Occlusion Limit will automatically increase to 400 mmHg to compensate for the effect of tubing flow resistance as infusion rates exceed 399.9 ml/hr.
26. When the air bubble reaches the pump, tilt the pump such that the distal (delivery end) is pointing upwards, toward the ceiling.	26. The alarm will sound as the air bubble passes into the air-in-line detector. The ALARM LED will illuminate. The RUN LEDs will extinguish. The LEDs in the volume to be delivered column will flash "Air". The LCD will display; Air In Line To Silence Alarm *Press MENU for help, or* Press HOLD.
27. Press the MENU Key.	27. The alarm will silence. The ALARM LED will extinguish. The HOLD LED will illuminate. The LCD will display; - Air in downstream tubing - Tubing improperly inserted in Air-In-Line Detector Press HOLD or Press RUN

Action	Observation
28. Press the HOLD key then press the MENU Key several times to quickly scroll to the bottom of the USER MENU. Cursor up to select "Biomed Options" and press the ENTER Key. Press the MENU Key two times to quickly scroll to the bottom of the BIOMED MENU. Cursor up to select "Check Configuration" and press the ENTER Key.	28. The LCD will display; Software Revision MP - H PP - L DP - A or B EXIT **Note:** This manual was written to match the above listed software revision. If your software revision does not match that which is indicated above and you have questions concerning software compatibility, please call Customer Service as instructed in Chapter 9.
29. Exit the MENU quickly by pressing the HOLD Key. Press the MENU Key. Press the ENTER Key to "Clear Total Volume."	29. The LCD will display; The present Total Volume of (some value)ml will be zeroed. Is this OK? YES NO Cursor ⟷ & Press ENTER
30. Press the POWER Key to turn the pump off.	30. The LED's in the Volume to be delivered column will display "----" until the device has completed the power down cycle. The AC LED will remain lit while the pump is plugged into an AC power supply.

3.7 Volume Delivery Accuracy

Equipment Required

1. Distilled water in an I.V. fluid container
2. Horizon™ pump IV set. (No older than 72 hours)
3. Electronic Balance
4. Collection vessel
5. Needle or dispenser tip with a Luer lock type connector.

Test Procedure: Volumetric

1. Connect the fluid delivery set to the fluid container.
2. Attach the needle to the delivery end of the I.V. set.
3. Completely prime the set with fluid so all the air is expelled from the set, and then close the roller clamp on the set.
4. Insert the cassette into the pump according to the instructions inside the door of the Horizon™ pump.
5. Close the door and press the POWER Key to turn on the pump.
6. Open all clamps and enter:

Volume	Rate	Pressure	Acceptable Limit
10 ml	120 ml/hr	300 mmHg	9.5 - 10.5 ml

7. Place the collection vessel on the balance, zero the reading, and suspend the needle over the collection vessel.
8. Press the RUN Key.
9. When the pump goes into the Keep Open mode, press the HOLD Key immediately. Make sure the actual volume delivered is between the acceptable limits listed in the above table.

   Note: 1 ml = 1 cc = 1 g of distilled water at room temperature (70° F)

10. Zero the reading on the balance. If the actual values are not within the specifications, test the pump with additional I.V. fluid delivery sets. If the values remain outside the specifications, return the pump to an authorized McGaw Service Center.

    Note: If using other test methods, in addition to the above, be sure to compensate for the adaptive energy processing used to conserve battery power and reduce noise as described in section 5.7.9.2 Motor Controllers. This dynamic processing of resistance to flow will cause the motor energy to rise and fall at the beginning of an infusion. This results in several momentary pauses of the motor as the energy is changed during the first few delivery cycles after the RUN Key is pressed. Manufacturers of biomedical test equipment will supply you with written instructions for use of their equipment when testing I.V. pumps which employ this type of energy processing.

3.8 Electrical Safety Check

Equipment Required

1. Medical equipment type electrical safety analyzer
2. AC power source
3. Horizon™ Pump I.V. set
4. I.V. container with suitable fluid in it

Test Procedure: Electrical

1. Plug the analyzer into an AC outlet.
2. Make sure the analyzer is functioning properly, according to your institutions protocol.
3. Plug the pump into the AC outlet of the analyzer.
4. Attach the probe to a single lead and touch it to the aluminum plate which supports the Daisy Chain outlet on the side of the pump or any protruding metal component.

   Note: If using a manual probe for your resistance checks you will need to make contact with either the metal frame of the power supply, located next to the daisy-chain outlet, or the stainless steel door latch. Being stainless steel the door latch makes for a difficult contact, you may need to scratch and scrape the probe on the latch.

5. Set the grounding selection to "No Ground".
6. Set the polarity to Normal.
7. Connect the fluid delivery set to the fluid container.
8. Attach the needle to the delivery end of the I.V. set.
9. Completely prime the set with fluid, then close the roller clamp on the set.
10. Insert the cassette into the pump according to the instructions in Chapter 3 of the Operation manual.
11. Close the door and press the POWER Key to turn on the pump.
12. Set an arbitrary primary rate and volume to be infused, then press the Primary RUN Key.
13. Press the Chassis Leakage button and make sure the reading does not exceed the UL 544 or the IEC 601-1 specifications as indicated below.

    Note: The measurement will be highest during the refill cycle of an infusion and will last only momentarily.

    Note: As of the date this manual was written the AC leakage current specifications for both UL 544 and IEC 601-1 is 100 microamps for patient vicinity equipment. When using the daisy chain feature on the Horizon™ (plugging one Horizon into

another), the chassis leakage current is cumulative. Therefore, test all units connected, as one system. The number of Horizons interconnected at any time should not exceed the 100 microamp limit. This specification should also be considered when using extension cords with any medical electronic device. The extension cord will increase the leakage current for that device and may thereby compromise the electrical safety of that device.

14. Set the polarity to Reverse.
15. Press the Chassis Leakage button again. Make sure the reading does not exceed the UL 544 or the IEC 601-1 specifications.
16. Press the HOLD Key.
17. Set the polarity to "Off."
18. Set the grounding selection switch to "Ground."
19. Press the Ground Wire Resistance button. Make sure the reading does not exceed the UL 544 or the IEC 601-1 specification.

    Note: As of the date this manual was written the ground wire resistance specification for a device with a non detachable power cord for UL 544 and IEC 601-1 is 200 milliohms.

20. Press the POWER Key on the pump.
21. Repeat steps 13 - 19, skipping step 16, with the power off.
22. Disconnect the pump from the analyzer. Disconnect the analyzer from the AC power source.

4 THEORY OF OPERATION, GENERAL DESCRIPTION

The following describes the basic theory of operation for the Horizon™ Pump. The organization of the material follows a general to specific, type format. The first section, section 4.1, gives an overall description of a few significant design features. The next section, section 4.2, is intended to give the reader a top level functional description. The detailed descriptions have been placed in a separate chapter, Chapter 5, for clarity. Related schematics and drawings (see Chapter 8) are cross-referenced where applicable. Appendix A lists the common abbreviations and symbols used throughout this chapter.

4.1 General Design Features

4.1.1 Patient Safety

Patient safety was a primary concern in the development of the Horizon™ Pump. The operation of the Horizon™ Pump incorporates a product design with features that optimize the safety of prescribed infusions.

Alarm and troubleshooting information are clearly visible, easy to read, and provide specific directions to correct problems as well as a list of possible causes.

The **Alarm Log and Operations Log** use the Horizon's real time clock to record up to 255 separate events to assist in troubleshooting problems and documenting a specific series of events.

Automatic dose rate calculations are performed by Horizon's unique Dose Mode. Nursing convenience and dosing accuracy are enhanced by this feature.

The Horizon's **ease of use** is one of the strongest factors contributing to patient safety. The method of operation is easy to learn. A wide variety of information provided by the data and information displays assist the user at each step of the infusion process.

Full visibility of operating parameters is accomplished with the LED data displays and the LCD information display.

Reduced cord clutter around the bed-side results from using the Horizon's daisy chain approach to power cord management. Multiple pumps can be daisy chained together, only one of which needs to be plugged into the wall.

The Horizon's **Anti-Freeflow mechanism** provides protection against inadvertent free flow when the Horizon™ Pump IV Set is removed from the pump.

Tamperproofing of the user selected operating parameters is provided in two levels. Rate changes during operation require the operator to validate the change by pressing the ENTER Key within six seconds. Complete lock out of the front panel is available by pressing the PANEL LOCKOUT key on the back of the pump.

User selectable variable occlusion pressure limits of 75 (approximately equal to gravity with fluid at 3.4 feet above the IV site), 100, 200, 300, 400, 500 and 750 mmHg settings allow the user to reduce the time to alarm.

The **QuickClamp™ pole mounting device** provides rapid and secure attachment to a variety of standard poles. While supporting the pump with both hands, the pump is attached to the pole, giving the user greater control of this process.

4.1.2 Ease of Operation and Repair

Ease of operation is enhanced by characteristics or features such as the QuickClamp™ pole clamp, stackability of pumps, daisy chaining of power cords, and a full array of displays that provide for optimal interaction between the pump and the user.

Ease of repair is facilitated through a modular approach to instrument design, assembly and disassembly. Rapid access to the interior of the pump is provided by a sliding case top. The alarm and operations logs provide a variety of time and date stamped information that will assist in the repair and service of the Horizon™ Pump.

4.1.3 Upgradability

The Horizon Modular Infusion System was designed with an eye toward the future. The modular design of the housing and internal assemblies makes access for service or upgrade simple. In addition, some connections are built into every Horizon™ for the addition of future options and accessories.

The most likely upgrade choice adds new software to the system. The software is contained in two Erasable Programmable Read Only Memory (EPROM) integrated circuits on the main board, which can be reached by simply sliding back the top cover. The EPROMs are installed in special carriers which protect their pins. Their sockets are polarized so that the EPROMs cannot be mixed up or plugged in

backwards. The Biomed Menu can be used to identify the installed software versions.

A second upgrade path provided is the option board. At the rear of the case bottom is a slide-out panel which can be replaced by a panel with an attached electronics board and connectors. This option board will connect to the Main PCB by a ribbon cable to a 50-pin connector.

A third upgrade path is the ability of the case bottom to accept a slide-on accessory which fits below the case bottom and is connected to the rest of the system through the rear panel. This capability opens up an even wider range of possibilities for the future of the Horizon™ pump.

4.2 Functional Description

The Horizon™ Modular Infusion System is a microprocessor-controlled volumetric infusion pump designed with advanced safety and convenience features for both the operator and the service technician. The modular internal design allows for rapid removal and installation of subassemblies for ease of problem diagnosis and repair.

The Horizon System Block Diagram, Figure 4-1, shows the mechanical and electrical arrangement of the various subassemblies and functional blocks that make up the pump. This is drawn at a general level and shows how the various subassemblies are interconnected. The major subassemblies are: Case Bottom, Power Supply, Main Battery, Bezel Mechanism, Door and Main board. Inside the Door Subassembly are the Display Board, LCD Controller Board, LCD Display Module and Transducer Board. There are three microprocessors which control most all functions, they are as follows: (1) Door Processor (DP), a NEC75108 OTP or mask programmed IC; (2) Management Processor (MP) a V75Plus IC and ; (3) the Pump Processor (PP), a 80C537 IC. Also present are Mechanical and electrical attachments for Option board(s) and or accessories.

Refer to chapter 5 for a detailed description of items discussed in this section.

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4.2.1 Case Bottom

The case bottom is the platform on which the rest of the Horizon™ is assembled. Attached directly to the case bottom are the fan, speaker, and the pole clamp. The fan is turned on by management software to cool the pump if its temperature rises too high. The power supply and battery attach to the case bottom with one self-locking nut. The bezel and door assembly slide into place on ribs in the case bottom, and the main board sits on posts above everything else. The case top slides on to the case bottom, locking the whole assembly together.

The case bottom and the other major case parts are plated with a metal layer to provide shielding for the whole system.

4.2.2 Power Supply

The Horizon power supply board is mounted in a sheet metal chassis, with a filtered, AC power inlet connector and a hospital-grade outlet for daisy chaining multiple pumps. The power supply connects to the main board and supplies 24, 16 and five volts to the system. The supply is a nominal 30 watt design using switching technology which reduces weight and increases efficiency.

The supply is attached to the case bottom and shielding, with a set of tabs and slots. Once the battery is placed above the power supply, it is made secure with one self-locking nut.

4.2.3 Main Battery

The Horizon can operate from a built-in 12 volt two amp-hour sealed lead-acid battery. This battery connects to and is charged by a circuit on the main board. The battery fits into a holder which attaches to the power supply and is held in place by the same fastener nut.

4.2.4 Bezel Mechanism and Door Assy.

The Horizon bezel is a plastic part to which is attached the pump mechanism components, the air-in-line block, and the tube pincher assembly. The door and bezel become one assembly when attached together by the door hinges. The door and bezel assembly is positioned in the case bottom via gasketed tongue and groove joints.

The door assembly serves two purposes. On the front surface, it supports the operator interface, with keypad, LED and LCD displays. On the inside surface, it captures the cassette and tubing, and holds the pressure transducer.

4.2.4.1 Pump Mechanism

The pump mechanism is that portion of the Horizon™ which mechanically controls the flow-rate, volume, and pressure of the fluid delivered. The various important parts of the pump mechanism are the bezel, the inlet valve, the transfer valve, and the restriction valve, the petal module, the refill piston, and the pressure transducer (figure 2-5). In the following paragraphs, the mechanism is described as it is seen from the front of the pump.

4.2.4.2 Pump Bezel

The front of the pump mechanism is formed by the bezel. It is the interface between the actual mechanics of the pump mechanism and the fluid delivery cassette. All three of the valves, the petal module, and the refill piston extend through the bezel to make contact with the cassette. In addition, the bezel supports the cassette, and the three cassette alignment pins on the face of the bezel align the cassette for proper operation.

The door of the pump limits the movement of the cassette, and helps to contain the pressure required for pressurized fluid delivery. The door must be closed and securely latched for the pump to operate.

4.2.4.3 Restriction/Outlet Valve

The restriction/outlet valve, see figure 2-5, is the right-most valve which extends through the bezel. The valve is under servo-control by the pump software and the restriction motor. The purpose of the valve is to provide the proper downstream resistance at the selected operating pressure. The restriction yoke has an optical sensor at the tip, called an optical yoke sensor, giving valve position information to the pump software.

4.2.4.4 Petal Module

The function of the petal module is to pressurize the delivery chamber of the cassette. The petal module is located just to the left of the restriction

valve, and has a protective rubber cover. It is pushed forward by the main stepper motor during fluid delivery, and retracts as fluid is pushed into the delivery chamber from the refill chamber during refill operation. The pump software obtains main motor position from the main motor optical encoder.

4.2.4.5 Refill Piston

The refill piston is inversely and mechanically linked to the main motor drive. This allows the cassette to refill while the petal module is pumping. The refill piston is the large disc to the left of the petal module, see Figure 2-5. The face of the piston is a magnet of special construction. It has unusually strong magnetic properties, which allows the piston to remain attached to the metal disk, part of the refill chamber of the cassette, even when refilling from a fluid supply positioned below the inlet of the pump.

4.2.4.6 Transfer and Inlet Valves

The transfer valve controls the transfer of fluid from the refill chamber of the cassette to the delivery chamber, and is located between the petal module and the refill piston. The inlet valve controls the flow of fluid into the refill chamber, and is located to the left of the refill piston. These two valves are mechanically linked to provide inverse operation, and are operated by the pump software via the transfer solenoid.

4.2.4.7 Mechanism Operational Sequence

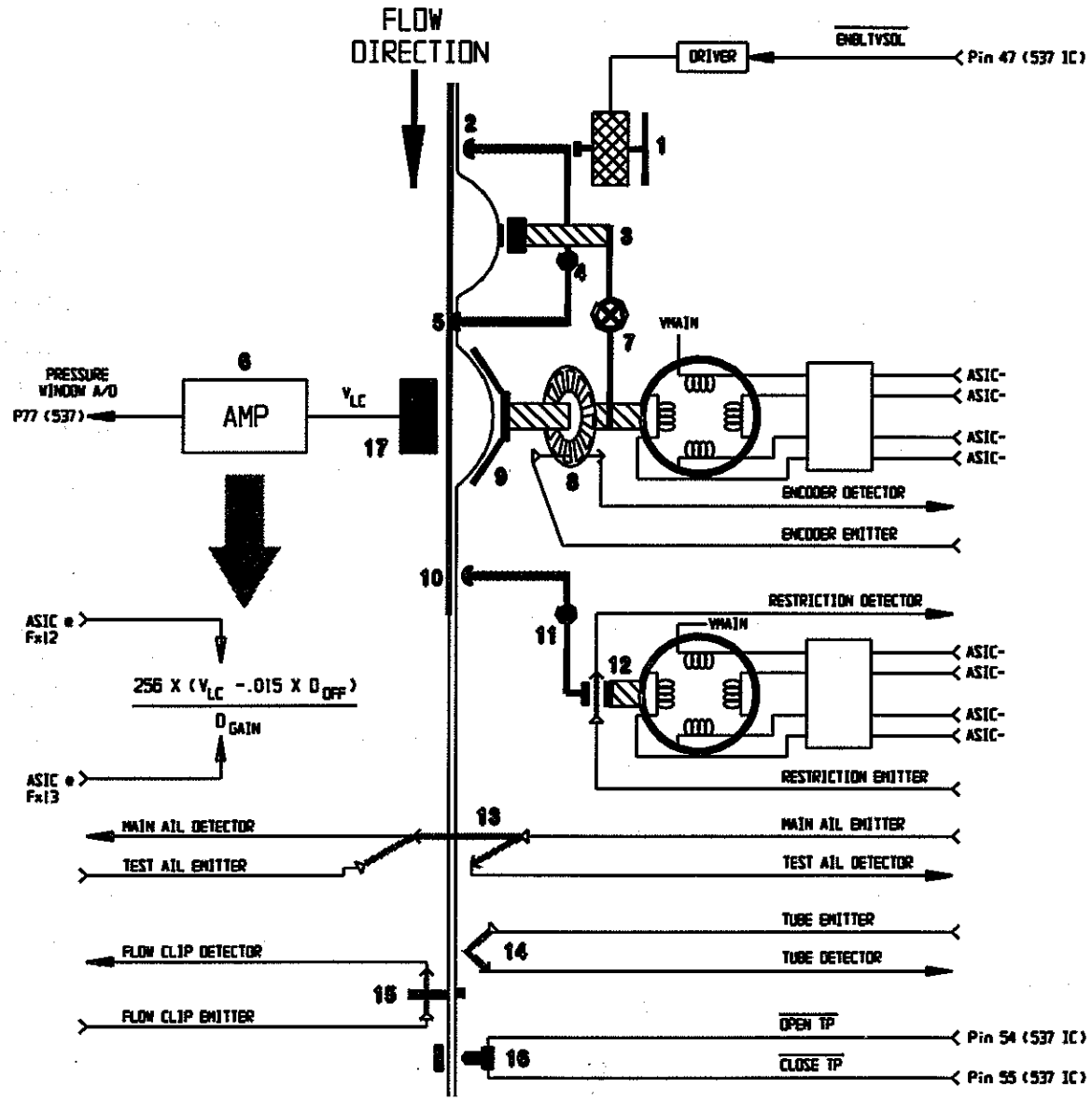

Figure 4-2: Mechanism Description and I/O Map

The Horizon™ uses a cyclical volumetric displacement method to deliver fluid. At the beginning of a pumping cycle, the restriction (10) and transfer (5) valves are closed, the inlet (2) valve is open, the petal module (9) is back and the cassette delivery chamber is full (cassette portion attached to 9), the refill piston (3) is forward and the cassette refill chamber (cassette portion attached to 3) is empty.

The petal module (9) is attached to the end of the main stepper motor shaft via a screw thread. Once the RUN key is pressed, the petal module assembly is driven forward until the selected delivery pressure (6) is achieved, and delivery begins. At the same time, the refill piston moves in the opposite direction, because it is mechanically connected through a pivot point (7). The main stepper motor drives the petal module forward a certain number of steps each cycle to deliver a precise amount of fluid. The delivery is approximately linear; for each main stepper motor step an equal amount of fluid is delivered. As delivery proceeds, the restriction valve opens and closes as the pump software reacts to varying fluid line conditions to maintain constant pressure in the delivery chamber.

As the petal module moves forward under stepper motor control, the refill piston moves back to allow entry of fluid from the container while the inlet valve is open. The encoder wheel (8) is optically monitored to give positive indication of motion. Pressure is monitored by a load cell (17) whose output goes to an amplifier (6). The amplifier output has separate offset and gain controls.

When the delivery cycle is complete, the restriction motor causes the restriction/outlet valve to close through a pivot point (11). The tip of the restriction motor is optically monitored to detect the point just before the valve starts to open. The transfer solenoid (1) energizes, causing the transfer valve to open and the inlet valve to close because it is mechanically connected through pivot point (4), and the petal module retracts as the refill piston moves forward to transfer fluid from the refill chamber to the delivery chamber. When the transfer is complete, the solenoid changes state and a spring forces the transfer valve to shut and the inlet valve to open and the delivery cycle is repeated.

The Air-In-Line block (13) is able to self-test both the main emitter and main detector. The Anti-Freeflow clip (15) and tube pincher (16) are provided for added safety.

4.2.4.8 Mechanism Interface Board

The mechanism interface board is the connection point between the main board and the bezel and door assemblies. One large connector mates with the main board and from there, connectors are provided for the; main stepper motor, main motor encoder, restriction motor, restriction optical

yoke, transfer solenoid, air-in-line block, tube pincher assembly and door assembly.

4.2.4.9 Air-In-Line Block

The air-in-line block is an optical bubble detector which the software uses to prevent pumping air to the patient. The set tubing is pressed tightly into the slot in the block by a spring-loaded pusher in the door. When a bubble above a certain size is detected, the pump will stop pumping and alarm.

4.2.4.10 Tube Pincher Assy.

The tube pincher assembly accepts the Anti-Freeflow Clamp portion of the set, and has a bar which physically stops flow by pinching off the set tubing. This bar can be opened by the operator using the "Push to Load" button for insertion of the Anti-Freeflow Clamp, and it can be opened by the software using the tube pincher solenoid when it is ready to start pumping. The tube pincher is shut to prevent fluid flow whenever the door is opened, or when there might be a pumping system problem. Also, power-down or internal power failure will cause the tube pincher to close. Internal latches prevent removal of the Anti-Freeflow Clamp unless the clamp is pulled onto the tubing by the operator, so that the set does not allow free flow of fluid as it is removed from the pump.

4.2.4.11 LED Display Board

The LED display board is the largest PCB inside the door. It contains the red LED display digits and the door processor integrated circuit. The door processor software receives commands from the management processor on the main board, controls the LED displays, processes keypanel inputs, controls the LCD display's visual contrast and backlight, controls the display and transducer board EEPROM memories, and senses ambient light.

4.2.4.12 LCD Controller Board

The LCD controller board is a small board which is attached to the back of the display board. It contains two surface mount integrated circuits. One is a specialized controller that accepts commands from the management processor and generates the signals to drive the LCD display

module, the other is a RAM memory IC in which the controller stores the images that are seen on the LCD screen.

4.2.4.13 LCD Display Module

The LCD display module is a factory-assembled liquid crystal display module containing the actual glass display screen, a printed circuit board containing driver electronics that control the 128 x 64 screen elements, and an electroluminescent backlit panel to allow viewing in low light. This module requires the LCD controller board to operate. In order to increase the backlite lifespan and reduce power consumption, the display is dimmed after three minutes if no keys have been pressed on the face of the pump.

4.2.4.14 Pressure Transducer Board

The transducer board is essential to the operation of the pumping mechanism. It is attached to the pressure transducer which is mounted in the door, Figure 2-5, and measures fluid pressure in the delivery chamber of the cassette. The circuitry on the board amplifies this pressure signal before it is sent to the pump processor on the main board.

The face of the pressure transducer is made of a rubber compound that transmits pressure from the window in the delivery chamber of the cassette to a sensor in the body of the transducer. The transducer face is covered with a special Teflon tape to protect it and reduce friction with the cassette.

4.2.5 Main Board

The main board is the center of the Horizon™ electronics system. It contains the management processor, pump processor and their associated EPROMS. The EPROMS hold the software programs which control the operation of the rest of the system. It mounts on four posts which are part of the case bottom, and has connections to the mechanism interface board, option board, main battery, power supply, fan, and speaker.

A switch located at the rear of the board is used to enable or lock out user access to the keypanel on the front of the pump while it is running. Also, at the rear of the board is an optical transmitter/receiver pair. These devices send and receive through a plastic window in the rear of the case top, and work in concert

with an Infrared Communications Module that clips on to the rear of the assembled pump to allow communications with the Horizon™ software.

The main board performs all pump mechanism control functions. It has a charging circuits for the batteries, and an interface for an option board. It controls the audio alarm, and has a backup alarm beeper and battery on board. It has special sockets for the two EPROM (Erasable Programmable Read Only Memory) integrated circuits which contain the management and pump processor software programs.

The main board is locked in place by ribs in the case top when it is slid on. This eliminates fasteners, and allows convenient access to the bezel/mechanism and power supply/battery.

5 THEORY OF OPERATION, DETAILED DESCRIPTIONS

5.1 Power Supply Board, Assy. 120062 or 501399, Schem. 256009 Rev F

WARNING: USE A LINE ISOLATION TRANSFORMER AND CAUTION WHENEVER WORKING ON AN ENERGIZED SUPPLY. FAILURE TO DO SO COULD RESULT IN BODILY HARM. A large portion of the Horizon™ power supply board is connected *directly* to the AC Line and contains *high voltages*.

The Horizon™ power supply has two major sections; an off-line switching supply that converts AC line voltage to 16 volts DC for charging the battery and running the pump, and a DC to DC converter to change either the 16 volt supply or the 12 volt main battery voltage to five volts DC for all logic circuits. A.C. power enters the supply through an electro-magnetic interference (EMI) filter with an integral input connector. From there, power is fed to the daisy-chain outlet and to the power supply board itself. Note that the daisy-chain outlet is not fused, which is why it should only be used for other Horizon pumps.

5.1.1 16 Volt Supply

WARNING: DO NOT WORK ON THIS CIRCUIT WITHOUT USING A LINE ISOLATION TRANSFORMER TO ISOLATE THE "NEUTRAL" INPUT CONDUCTOR FROM EARTH GROUND. FAILURE TO DO SO COULD RESULT IN BODILY HARM. The ground reference shown in the primary or high voltage side of the 16 volt supply is not the same as circuit ground throughout the rest of the pump, and it is different from earth ground.

The 16 volt supply section can use a nominal AC line supply of either 120 VAC or 240 VAC. Two jumpers soldered into the board must be removed for 240 VAC operation. The supply has a fuse in each input line, which is required for 240 VAC capability. There is then a filter section for removal of electromagnetic interference (E.M.I.). A thermistor, RT1, has a relatively high resistance when cold, which limits the inrush of current when the supply is first plugged in and the filter capacitors are uncharged. Once this happens, the thermistor warms up and its resistance does not affect supply operation. VR1 and VR2 are called Metal Oxide Varistors, or MOV. They absorb high transient voltage spikes which may occur on the line. VR2 is only effective when the 240 VAC jumper JMP1 is cut. Rectifier CR3 acts as a bridge rectifier when configured for 120 VAC and as a half-bridge when configured for 240 VAC.

The control element in this supply is integrated circuit U1. It has a built-in voltage reference and a high frequency oscillator whose frequency (about 50 KHz) is set by R4 and C4. When the AC line cord is plugged in, U1 is supplied start-up voltage through R1. As soon as its Vcc input rises above eight volts, it begins to operate. U1 turns on field effect transistor (FED) Q1. This connects the primary (pins 1 to 10) of transformer T1 across the high voltage DC supply. Rising current through the inductance of T1 is sensed by resistor R24 until it reaches the peak set by U1, and Q1 is turned off. Two snubber circuits around diodes CR1 and CR2 absorb the high voltage inductive spikes caused by the switching of Q1. These current pulses though T1 create a voltage across the secondary #1 (pins 7 to 8) which is rectified by CR10 and filtered by C24 and L3, to build up to 16 volts. The fuse in series with T1's primary protects the transformer and primary circuits should Q1 fail in the on condition.

Since T1 is the isolating component between the line voltage and the secondary circuit, there is no direct feedback between the 16 volt output and U1. Instead, secondary #2 of T1 (pins 4 to 5) is used for control. Since secondary #2 is a part of the same transformer, its output is representative of the 16 volt secondary. The output of secondary #2 is rectified by CR3, filtered and fed to U1. As input pin 2 of U1 reaches 2.5 volts, the on-time of Q1 is reduced, and the 16 volt output stabilizes. Overcurrent protection is provided by the peak-current sensing at R24. Secondary #2 also is rectified by CR4 and used to keep U1 supplied with current during any sags in the high voltage supply.

This 16 volt supply output has a maximum output of approximately 1.8 amps, and is used to power the battery charger and mechanism motors and transfer solenoid in the pump mechanism. When the AC plug is disconnected, the main battery takes over this function. This voltage is distributed to the rest of the pump electronics and is referred to as Vmain. Normally the 16 volt supply is capable of supplying all current required by the pump, but the latching solenoid used to open the Tube Pincher at the beginning of delivery requires about three amps, so that the main battery must assist in this one instance, even when the pump is plugged in.

5.1.2 5 Volt Supply

The second part of the Horizon™ power supply is the 5 volt supply. The controller IC is the same type as used in the 16 volt section, and the circuit configuration is similar, with FET Q2, switching transformer T2 and CR7 rectifying the secondary to get five volts out. However, since this is all low voltage circuitry, the five volt output is regulated directly by U2. This supply section is powered

either by the 16 volt output from the power supply, or the main battery. If the 16 volt supply falls below the main battery level, circuitry on the main board ensures an immediate switchover.

Secondary #2 of T2 is used to generate an unregulated 24 volt output for use in the system. This output is clamped with a zener diode to avoid too high an output when the 5 volts is loaded down. Positive temperature coefficient thermistor RT2 protects the supply components if this output is shorted, by rising in resistance as the current passing through it rises. Once the short has been removed it will return to normal.

5.1.3 EEPROM Interface

Integrated circuit U3 is an Electrically Erasable Programmable Read Only Memory (EEPROM), which contains 1024 bits of memory, arranged as 64 words of 16 bits each. The contents of this EEPROM can be read, erased, and written to with one data, one clock, and one chip select line, all connected to the main board and controlled by the management processor. The contents are non volatile; they do not change when the power goes away, so configuration and characterization information for the power supply can be stored for use by management software.

5.2 LED Display Board, Assy. 120064 or 435079, Schem. 256004 Rev A

The LED display board acts as the central connection point inside the Horizon™ door assembly. The 34-conductor cable from the bezel assembly brings all signal and power lines to the display board, and from there some are distributed to the transducer and LCD controller boards.

5.2.1 Door Processor

The heart of the display board is the door processor IC This is a single-chip microprocessor with an internal program which controls the LED displays, the interface to the membrane keypanel, the inverter for the LCD display backlight, and the contrast voltage supply for the LCD display. Secondary functions it performs are reading the external light sensor and controlling the nonvolatile configuration memories on both the display and pressure transducer boards. Memory internal to the door processor is used to store display content and other control status information sent from the management processor. This data is lost at power-off and must be restored from the management processor when power is restored.

The door processor behaves as a slave to the management processor on the main P.C. board. It has a built-in crystal-controlled five megahertz oscillator, and is reset by a signal from the management processor. After reset, it turns on the AC indicator LED and waits for commands from the management processor. Communication with the main board is controlled by the management processor and uses four signal lines: SYNCDAT, SYNCCLK, DOORCTS, and DOORRTS. Communications use a synchronous serial format, with the synchronous clock generated by the management processor. If the management processor wishes to send a message to the door processor, it sends one or more bytes with one clock pulse for each bit. If the door processor wishes to send a message to the management processor it uses DOORRTS to request it, and the management processor uses DOORCTS to indicate its readiness, and the message byte is then transferred by the management processor's clock pulses. These message signals can be observed even when the pump is idle, since each processor sends an "I'm O.K." message every few seconds for safety purposes.

Messages between the two processors have parity bits so that communication errors can be detected, and an alarm generated.

5.2.2 LED Displays

The primary function of the door processor is the control of the LED displays. There are 18 digits of seven segments each and seven individual indicator LEDs. Counting the four decimal points which are used, there are 137 LED segments which must be controlled by the processor. This is accomplished by using a technique called multiplexing, in which a smaller group of digits is turned on, along with the desired segments in those digits, for a short time at a higher than normal brightness. Then another group of digits and segments is turned on using the same processor pins. If this is done rapidly enough, the eye is fooled into thinking that the LEDs are on all of the time at normal brightness.

On the Horizon™ display board, the LED digits are divided into five groups. The seven indicator LEDs are treated as if they were another digit. Digit driver U4 is controlled from the door processor so that only one group of digits is fed power at a time. Five shift clock pulses from the door processor move the correct "on" bit into the digit driver once each multiplex period. At the same time that the digit group is powered up, individual segment drive pins on the processor itself are turned on, so that the desired segments in that group of digits are turned on. Current flow through an individual segment travels as follows: from Vcc (5 volts) supply through transistor Q1 to digit driver U4, from one output of U4 to the LED

anode, through the LED to a current limiting resistor, and then through a door processor port pin to ground.

Transistor Q1 is used by the door processor to test LED segments during the multiplexing process. If Q1 is turned on by the door processor, the voltage drop across it is very low. To test a single LED segment, Q1 is turned off, and the proper digit group and segment drive pin are turned on. The current flowing through the LED segment produces a voltage drop across resistor R2, and this voltage can be measured by a door processor threshold port pin. This measurement, which can split 5 volts into 16 different levels, can detect if the LED is open. If the segment is bad, then the door processor will send a failure message to the management processor, and an alarm will result. The testing of a segment takes very little time, and is an ongoing process while the LED display is active.

The information to be shown on the LED displays is sent from the management processor and is stored in the door processor internal memory. Brightness of the LED digits is controlled by the percentage of time that the digits are on during multiplexing. The management processor sends brightness commands to the door processor, which makes one row of LEDs brighter than the other to indicate which row will be affected when the keypanel is used. When an alarm occurs, the management processor commands the door processor to blink certain digits.

Contents of the door processor memory that controls the LED display contents can be sent back to the management processor for checking display integrity.

5.2.3 Keypanel Interface, Assy. 112027, Schem. 112027 Rev F

The second most important function of the door processor is to interface with the switches in the membrane key panel. The keypanel connects to the display board through two 7-conductor flexible tails. The POWER or on/off switch in the keypanel connects straight through to the main PCB to control power-up and power-down sequences. The other keypanel internal switches form a five by six matrix which is connected to the door processor circuitry. Each switch on the panel is connected between one "row" and one "column" of this matrix, which is scanned for pressed keys during part of the display multiplexing process. During a time when they are not driving an LED segment, one of six door processor ports is held low. This pulls one of six keypanel columns down to ground through a diode. The five keypanel rows are each pulled up to Vcc by a resistor, and are tied to five door processor inputs. If a switch contact on that keypanel column is closed when this happens, then that switch's row is pulled low so that one of

the door processor's inputs is pulled low. In this way, the software can tell by scanning all six columns which switches are closed. This scanning process is very rapid and is synchronized with the LED multiplexing. If a switch is held down long enough, about 1/30th of a second, then the door processor will send a message to the management processor saying that the key has been pressed. If the key remains held down, then a periodic "key still down" message will be sent.

A flexible circuit jumper is part of the keypanel tail, and ties one of the five row lines to a special door processor pin. The processor can use this pin to tell which line the jumper is tied to, which tells it the specific keypanel type. In this way, future keypanels with different switch arrangements or graphics could be identified for use with special software versions.

If the door is open, the management processor will generate audio clicks if the keypanel switches are pressed, but no other action will be taken. This is to prevent accidental data or status changes caused by something underneath the open door.

5.2.4 Ambient Light Sensor

Sensor CS1 on the display board is a light detector IC in a transparent package. It is positioned behind the red LED window and its output is read by the door processor. This light information is sent to the management processor so that it can determine the brightness level commands sent back to the door. This way, the LED's are not too bright in a dark room, but can still be seen next to a bright window.

5.2.5 LCD Contrast Voltage

Integrated circuit U3 generates a regulated voltage that is supplied to the LCD display module, which controls the visibility, or contrast, of the display elements on the LCD screen. U3 and the surrounding circuitry takes Vmain, which ranges from 11 to 16 volts, and generates a negative voltage supply (Vlcd). This voltage is regulated by U3, but it is influenced by two other factors. First, since LCD contrast is affected by temperature, thermistor, CT1, causes Vlcd to change with temperature to match the display. If the display is cold, the voltage should be more negative, if it is warm, the voltage should be less negative. In addition, three output pins from the door processor can shift Vlcd. These three pins can be set to eight different combinations (0-7) which can give eight different levels of Vlcd, which are controlled by software from the User Menu item "Set LCD Contrast".

This setting is saved in management processor RAM memory and is restored at power-up. Vlcd has a normal adjustment range from -7 to -8.5 volts.

The door processor uses transistor Q4 to supply Vlcd to the LCD display. At power up, it is not turned on until the LCD controller has been initialized and the management processor sends an "LCD on" command to the door.

5.2.6 LCD Backlight Supply

CAUTION: The backlight voltage passes from the display board, through the LCD controller board, and to the LCD display module. If this connection is broken and the inverter is on, it will emit a high frequency audible noise, and it can be damaged by operating this way for any length of time.

The LCD display module contains an electroluminescent panel which is used to backlight the display so it can be viewed in dim lighting conditions. This backlight requires a power supply of 100 volts AC at 400 Hz frequency. This voltage is generated by a DC to AC converter mounted on the back of the display board. The door processor, commanded by the management processor, controls the Vmain supply to the inverter, which turns the backlight on and off. An electroluminescent panel has a limited operating life, over which it grows dimmer, so the management software turns off the backlight when no user interface activity is taking place.

5.2.7 EEPROM Interface

The door processor controls two memory IC's, called Electrically Erasable Read Only Memories, one on the display board itself (U2) and one on the pressure transducer board. Each of these IC's contains 1024 bits of memory, arranged as 64 words of 16 bits each. The contents of each memory IC can be read, erased, and written to with one data, one clock, and one chip select line. The contents are nonvolatile; they do not change when the power goes away, so configuration and characterization information for each board can be stored for use through commands from the management software.

5.3 Liquid Crystal Display (LCD)

The Horizon™ Liquid Crystal Display (LCD) is composed of two parts, the LCD controller board and the LCD display module. The LCD controller takes commands and data from the management processor and saves them in its dedicated RAM memory. It then creates clock and data signals to control the actual display elements on the LCD display module.

5.3.1 LCD Controller Board, Assy. 120089 or 435078, Schem. 256005 Rev A

The LCD controller board is a small board attached to the rear of the display board. It contains two surface mount integrated circuits, one a 32 kilobyte RAM memory IC (U2), and the other an LCD controller IC (U1). The function of the controller is to accept commands and data from the management processor and send signals to the driver electronics in the LCD display module. The controller has its own five megahertz crystal which sets the timing for driving the display. Jumper E1-E2 controls how the controller-to-management processor interface works and should remain uncut. At power up the controller is reset by a signal from the management processor that also resets the door processor.

The management processor sends data indicating which of the 128 x 64 elements (pixels) on the LCD screen should be on (dark) and which should be off (light), and the controller saves this information in a RAM IC. This information is sent on an 8-bit bidirectional bus, which comes from the main board and passes straight through the display board. The interface between the RAM and the controller is a separate bus with address and data lines for the full 32 kilobytes of memory space. Although each LCD screen represents 8K pixels, or one kilobyte, multiple screens can be stored before they are needed, to speed up screen changes.

The signals the controller sends to the LCD module are similar to video signals; the display drivers control rows and columns of pixels, and controller clock pulses move data into the drivers four bits at a time, with sync pulses shifting from row to row and column to column. As it steps through, the controller retrieves the data for the next pixels from the RAM.

5.3.2 LCD module, Assy. 501262

The Liquid Crystal Display module is a combined LCD screen, driver electronics board, and electroluminescent backlight. It is supplied by Epson U.S.A. and is not repairable to the component level. It is a "transflective" type of display, with a built-in reflector for viewing in brighter light, and a transmissive backlight for viewing in dim or no light.

The LCD panel contains 1024 square elements (pixels) arranged as a 128 pixel wide by 64 pixel high array. Control signals for the display are generated by the LCD controller, and are all logic level signals. The actual voltage (Vlcd) that turns on the LCD pixels is a negative voltage (-7 to -8.5 volts) generated on the display

board and adjusted (under operator control through the User Menu) by the door processor. This voltage also varies with temperature, since the behavior of the LCD is temperature sensitive. This allows the display to work over a temperature range without requiring adjustments.

The backlight is a solid-state electroluminescent (E.L.) sheet which glows when energized by a 100 volt AC signal generated on the display board. The glowing phosphors in this panel tend to glow less brightly as time goes on, so the backlight is turned on and off under management software control. After the pump starts running, the backlight is turned off to extend its useful life. Once the backlight is turned off, pushing any keypanel key will turn it back on so that the display can be seen in dim light.

5.4 Pressure Transducer Board, Assy. 501263 , Schem. 256006 Rev C

The pressure transducer board assembly senses pressure in the cassette delivery chamber through a pressure sensing membrane in the cassette, by means of a pressure transducer. The pressure transducer output is adjusted for offset errors and amplified. The amplified pressure signal is converted to a differential signal prior to transmission through the display board and finally to the main board, in order to reduce its susceptibility to noise.

5.4.1 Pressure Transducer Circuits

The pressure transducer converts the pressure applied to its surface membrane to a differential output voltage. The pressure transducer is powered by a constant current source, which is generated by op amp U2A, 2.5 volt reference CR1, and a 1.65K ohm current setting resistor, R4. Op amp U2A maintains 2.5 volts across resistor R4, which results in a constant 1.5 milliamps out of the pressure transducer supply return terminal. The differential pressure transducer output is sensed by op amp U3A, which has unity gain.

5.4.2 Offset, Gain and Output Circuits

The sensed pressure transducer output signal is amplified and adjusted for offset errors, by means of op amp U2B. Amplifier U2B is constructed as a summing amplifier, with a signal gain of 47.5. Amplifier U2B sums the inputs from the pressure transducer sense amplifier, the 2.5 volt reference CR1, and the -2.5 volt reference CR2. The contribution from the sensed pressure signal is scaled by the ratio of feedback resistor R5 to input resistor R2, which provides a signal gain of 47.5. The contribution from the 2.5 volt reference is scaled by the ratio of feedback resistor R5 to input resistor R8. Therefore, R8 is selected to correct

for negative offset errors. The contribution from the -2.5 volt reference is scaled by the ratio of feedback resistor R5 to input resistor R7. Therefore, R7 is selected to correct for positive offset errors.

Op amp U3B inverts the offset adjusted pressure signal, to complete the formation of a differential output with maximum range.

5.4.3 EEPROM

The pressure transducer board contains a 93C46 1024 bit EEPROM, U1. The EEPROM provides the capability for nonvolatile storage of configuration data. It is accessed through a bidirectional serial data line, a clock line, and a chip select line, which are all connected to the door processor on the display board. The door processor transmits write data and receives read data on the data line. It transmits clock pulses on the clock line, and transmits EEPROM chip select signals on the EEPROM chip select line.

5.5 Pressure Transducer Board, Assy. 501389, Schem. 256006 Rev C

This board differs from Assy. 501263 only by a few reference designators and an updated schematic revision letter.

5.5.1 Pressure Transducer Circuits

The pressure transducer converts the pressure applied to its surface membrane to a differential output voltage. The pressure transducer is powered by a constant current source, which is generated by op amp U2A, 2.5 volt reference CR1, and a 1.65K ohm current setting resistor, R3. Op amp U2A maintains 2.5 volts across resistor R3, which results in a constant 1.5 milliamps out of the pressure transducer supply return terminal. The differential pressure transducer output is sensed by op amp U3A, which has unity gain.

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feedback resistor R2 to input resistor R8. Therefore, R8 is selected to correct for negative offset errors. The contribution from the -2.5 volt reference is scaled by the ratio of feedback resistor R2 to input resistor R7. Therefore, R7 is selected to correct for positive offset errors.

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5.6 Mechanism Interface Board, Assy. 120079, Schem. 256008 Rev A

The mechanism interface board is the connection point between the main board and the bezel and door assemblies. One 100-pin connector mates with the main board and from there, connectors are provided for the main stepper motor, main motor encoder, restriction motor, restriction optical yoke, transfer solenoid, air-in-line block, tube pincher assembly, and door assembly. The connectors are polarized and sized so that the mechanism components cannot be plugged in incorrectly. The door cable assembly is built with special high flex-life ribbon cable to withstand the large number of door operations over the life of the pump.

The interface board also contains its own EEPROM memory integrated circuit controlled by the management processor for configuration control.

5.7 Main Board, Assy. 120081, Schem. 256003 Rev I

The Main Board utilizes a dual processor architecture, for both efficiency and reliability. One of the processors, the management processor, is primarily responsible for interpreting operator inputs, initiating fluid delivery operations, and generating display information. The other processor, the pump processor, is primarily responsible for controlling fluid delivery operations, as directed by the management processor. An application specific integrated circuit (ASIC) generates the waveforms that control the two motors during fluid delivery, as directed by the pump processor. The ASIC also provides all address

decoding for the management processor, and provides the interface between the external photo-interrupter LEDs and both processors. A block diagram of the main board's major circuits and their connections to the external subsystems is shown in Figure 4-1, and is described below. A picture of the main board is included to help identify selected components.

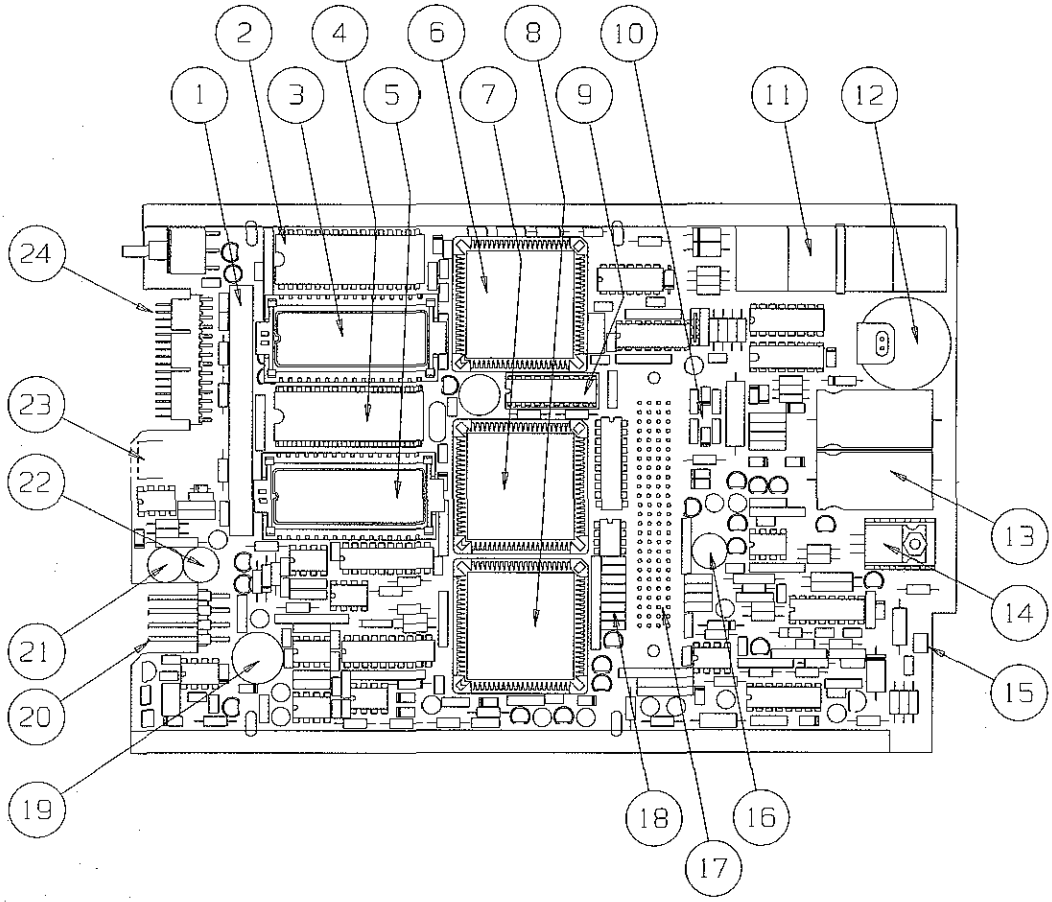

Figure 5-1: Main Board Layout Description

1. Option Board Connector
2. Pump Processor Memory
3. Pump Processor EPROM
4. Management Processor Memory
5. Management Processor EPROM
6. Pump Processor, 80C537
7. Management Processor, V25PLUS
8. ASIC
9. EPLD
10. Tube Pincher Drivers
11. 4.8 Volt NiCad Battery
12. 3.0 Volt Lithium Battery
13. Tube Pincher Caps
14. Main Battery Charger
15. Touch Switch for manual turn off of Backup Alarm
16. Fuse 3, Tube Pincher, 1.25 amp
17. Bezel/Door Connector
18. Motor Drivers
19. Backup Alarm
20. Main Battery Connector
21. Fuse 1, Battery Testing, 0.16 amp
22. Fuse 2, Main Battery Switching,
23. Fan/Speaker Connector

24. Power Supply Connector

5.7.1 Management processor

The management processor, U11, is a V25 Plus microcomputer, which is software compatible with the 8086 microcomputer. It uses a 16 bit internal data bus and an eight bit external data bus. The V25 Plus can directly address 1M byte of memory and 1M byte of I/O. Memory accesses are controlled by Memory Request (MREQ), Memory Strobe (MSTB), and Read/Write (R/W). I/O accesses are controlled by I/O Strobe (IOSTB) and Read/Write (R/W). The V25 has two serial channels and four multifunction I/O ports, including one eight bit analog comparator port for discrete or analog inputs. The signals monitored by the eight bit analog comparator port are listed in Table 5-1. The microprocessor operates at a clock frequency of 12 MHz, which is supplied by a crystal and an internal oscillator.

Table 5-1: V25 Analog Detector Inputs

Port Pin	Signal	Description
PT0	SW1	Discrete output from power switch circuit
PT1	RESTRBUF	Buffered discrete restriction valve flag
PT2	TUBPINBUF	Buffered discrete tube pincher flag
PT3	FLOCLIPBUF	Buffered discrete Anti-Freeflow Clamp flag
PT4	AILBUF	Buffered discrete air-in-line signal
PT5	-	Not used
PT6	ISPKR	Analog speaker current signal
PT7	AILTESTBUF	Buffered discrete test air-in-line signal

The management processor program is stored in an external 256K byte EPROM, U13, and data is retained in an external 128K byte RAM, U10. The RAM write line is gated by Memory Strobe with a 74AC11032 NAND gate, U7A, to provide the necessary address setup time. The RAM is backed up with a 3 volt on-board battery, BT2, which is switched in or out by a 691 power supervisory integrated circuit, U5. Therefore, data will be retained in RAM even if the board is removed from the system. Pullup and pulldown resistors on the data bus ensure that an Interrupt 3 instruction will be retrieved by the microcomputer if non-existent memory is addressed.

5.7.2 EEPROM bus

The management processor directly controls four of the Horizon™'s six 93C46 1024 bit EEPROM's and the time-of-day integrated circuit via a bidirectional, synchronous serial bus. The EEPROM's provide the capability for nonvolatile storage of configuration data. They are accessed through a bidirectional serial data line, a clock line, and chip select lines. The main board EEPROM is designated U14. Management processor port pin 26 is used to transmit and receive data on the data line, and port pin P27 is used to drive the clock line. The four EEPROM select lines are generated and latched in the ASIC. They are controlled by bits 0-3 of the command byte that is located at address 2200 hex in the management processor's I/O space.

5.7.3 Door Interface Bus

The management processor communicates with the external door processor via a bidirectional, synchronous serial bus. The management processor uses port pin P14 to transmit and receive data on the data line, and it uses port pin P17 to drive the clock line. The door processor requests permission to transmit a message by raising a flag on the DOORRTS line (management processor port pin P07). The management processor then grants permission to send by raising a flag on the DOORCTS line (management processor port pin P21). The DOORRTS and DOORCTS lines are not used when the management processor sends messages to the door processor, since the door processor is normally ready to receive. The management processor can reset the external door processor with the RESETDOOR line (port pin 22).

5.7.4 Option Interface

The option interface provides power to and communicates with an option card with an onboard configuration EEPROM. A subset of the management processor bus is routed directly to J5, the option interface connector, to allow the management processor to communicate with the option card. This subset consists of eight data lines, five address lines, one memory strobe line, and one read/write line. An option select line is generated by the ASIC. It is decoded from management processor memory address space, from 600 hex to 61F hex. In addition, the management processor provides two general purpose IO/interrupt lines (port pins P11 and P13) and 3 DMA channel control lines. The main board power-on reset line and the EEPROM bus, with the option EEPROM select line, are also routed to the option interface connector.

Several of the option interface lines are provided strictly for diagnostic purposes, within the McGaw manufacturing facility. The door interface bus and the interprocessor communications bus are routed to the option interface connector to provide a means of monitoring routine communication traffic between the processors during normal operation. One of the two full duplex asynchronous serial ports in the pump processor is also routed to the option interface connector, to provide a means of monitoring special diagnostic messages and setting up operating conditions with special test software. Similar diagnostic commands and messages can be transferred to and from the management processor via the management processor bus subset described above. The option card can also force non-maskable management processor interrupts and main board general resets via the TESTNMI and TESTRESET lines. These lines cannot be accessed without a special test option card, in order to eliminate any possibility of interference with the instrument's operation in normal use.

Seventeen power and ground lines complete the option interface. They are as follows: 4 VMAIN (12V/16V), 2 VCC (5V), 2 VBIAS (24 V), 2 V+ (8V), 2 V- (-8V), and 5 ground.

5.7.5 LCD Interface

The management processor can write commands and display data to, and read status and display data from, the external LCD controller, via an eight bit parallel data path. The eight bit data path is buffered by a 74HC245 octal bidirectional buffer, U9. The management processor Memory Strobe is gated with the Read/Write line by two 74AC11032 NAND gates, U7B and U7C, to produce an LCD read and an LCD write line. An LCD select line is generated by the ASIC. It is decoded from management processor memory address space, from 400 hex to 401 hex. A single address line, A0, buffered by a 74AC11032 NAND gate, U7D, provides 2 LCD read addresses and 2 LCD write addresses. This allows the management processor to write LCD commands, write LCD data, read LCD data, and read LCD status.

5.7.6 IR link

The management processor can transmit serial data to and receive serial data from an external host by means of a full duplex, asynchronous, infrared (IR) communications link. The infrared communication path allows a fluid tight, electrically isolated interface. One of the two serial ports in the management processor is dedicated for this purpose. Transmit data from the management processor serial port output pin is re-driven by PNP transistor Q36, and then

routed to an LED, D2, which produces infrared light at 940 nm. The LED is positioned at the rear of the main board, facing a window that is transparent to infrared light. An optional external IR communications module converts the infrared transmit data to RS 232 levels, and completes the transmission to an external host. RS 232 data from the host is similarly converted to infrared light by the external IR communications module, and detected by a phototransistor, D3, located at the rear of the main board. This data is routed directly to the management processor serial port input pin. The data is sent as ASCII text using a baud rate of 9600, no parity, 8 data bits and 1 stop bit. With this format an entire log, alarm or operation, can be downloaded in approximately 90 seconds. Refer to the Operation Manual, chapter 6 section titled "Check Alarm Log" or "Check Operation Log".

5.7.7 Pump processor

The pump processor is an 80C537 microcontroller, U3, which is based on a superset of the 80C31 architecture. With 16 address bits, the 80C537 can directly address 64K bytes of program memory and 64K bytes of data memory. Eight output pins are dedicated to the upper eight address bits, but the lower eight address bits are multiplexed with the eight bit data bus. Therefore, the lower eight address bits must be stored in the 74HC373 latch, U16, with the falling edge of Address Latch Enable (ALE) before the eight data bits are presented on the same lines. Program memory fetches are controlled by Program Store Enable (PSEN), data memory reads are controlled by Read (RD), and data memory writes are controlled by Write (WR).

The pump processor program is stored in an external 64K byte EPROM, U6, and data is retained in an external 128K byte RAM, U1, although only half the RAM can be accessed. Pulldown resistors on the data bus ensure that a NOP instruction will be retrieved by the microcontroller if nonexistent memory is addressed.

In addition to its address and data ports, the 80C537 has five eight bit multifunction I/O ports, two serial channels, and 12 A/D inputs. The signals monitored by the internal A/D converter are listed in Table 5-2. The 80C537 operates at a clock frequency of 12 MHz, which is supplied by a crystal and an internal oscillator.

Table 5-2: 80C537 A/D Converter Inputs

Port Pin	Signal	Description
P70	VTEMP	Indicates temperature inside case
P71	VMAIN	Indicates voltage on 12V/16V rail
P72	VBATTMON	Indicates voltage at main battery
P73	IMAINMON	Indicates current from 12V/16V rail
P74	2P5REF	Indicates voltage on 2.5V reference
P75	AILHWCONFIG	Indicates AIL H/W compatibility
P76	AILSWCONFIG	Indicates AIL S/W compatibility
P77	WINDOWPRES	Processed pressure transducer signal
P80	ISPKR	Indicates speaker current
P81	VCC	Indicates voltage on 5V rail
P82	VBIAS	Indicates voltage on 24V rail
P83	SW1	Discrete output from power switch circuit

5.7.8 Interprocessor Communications Bus

The management processor and the pump processor communicate with one another through dedicated full duplex asynchronous serial ports. The management processor can transmit messages to the pump processor at any time over the V25T0537 line, and the pump processor can transmit messages to the management processor at any time over the 537TOV25 line.

5.7.9 ASIC

The ASIC, U19, interfaces with both the management processor bus and the pump processor bus. It performs all address decoding for the management processor, performs I/O address decoding for the pump processor, generates stimuli for external sensors, and generates motor drive waveforms for the main motor and restriction motor.

5.7.9.1 Address Decoding and Stimuli

The addresses decoded by the ASIC are shown in Table 5-3. Note that the AIL LED, test AIL LED, main motor encoder LED, restriction valve LED, tube pincher LED, Anti-Freeflow Clamp LED, and the door switch can all be energized by either the management processor or the pump processor.

Table 5-3: ASIC Address Decoding

Function	Mgmt Proc Mem Addr	Mgmt Proc I/O Addr	I/O Addr	Pump Proc Comments
EPROM Select	0-3FF			Vectors
LCD Select	400-401			
Option Select	600-61F			
RAM Select	800-3FFFF			Data
EPROM Select	40000-FFFFF		Program	
Test AIL LED	2000, DB0	F011, DB0	Latched	
Tube Detector LED	2000, DB1	F011, DB1	Latched	
Combined Stim. *	2000, DB2	F011, DB2	Latched	
AIL LED	2000, DB3	F011, DB3	Latched	
DAC		F012-F013		
Main EEPROM Sel.	2200, DB0		Latched	
Mech EEPROM Sel.	2200, DB1		Latched	
Power EEPROM Sel.	2200, DB2		Latched	
Option EEPROM Sel.	2200, DB3		Latched	
TOD Select/Reset	2200, DB4		Latched	

* The combined stimulus signal, STIM, energizes the main motor encoder LED, restriction valve LED, tube pincher LED, Anti-Freeflow Clamp LED, and door switch.

5.7.9.2 Motor Controller

The ASIC receives motor commands from the pump processor bus, and generates pulse width modulated (PWM) waveforms for the main motor and the restriction motor. Both motors are four phase, unipolar stepper motors. A single command from the pump processor can result in no more than a single step from a single motor, so the motors are always under strict processor control. The 8 PWM motor waveforms are re-driven by 8 N-channel FET's with transient suppression diodes. The resulting drive signals are then routed to the motor windings. The 8 PWM motor waveforms in the ASIC can be completely inhibited by the LATALARM signal from the EPLD. See the section on the Power Controller EPLD for a description of LATALARM.

The ASIC controls the duty cycle of the PWM waveforms, as directed by the pump processor, which in turn determines the average current through the motors. The pump processor can also command the ASIC to ramp the

duty cycle of the PWM waveform up or down over a selectable period of time, at the beginning or end of a motor step. This is done to reduce the acoustical noise when a motor step is applied.

5.7.9.3 ASIC Timers

The ASIC also contains two programmable timers, one for each motor, to ensure that the motor stepping rates selected by the pump processor are accurate. Any pending main motor step command is automatically executed when the main motor timer times out. In addition, the main motor timer issues interrupts to the pump processor at three different points: when the timer times out, three timer clock periods before the timer times out, and seven timer clock periods before the timer times out. The main motor timer clock period can be programmed to be either 341 microseconds or 2.73 milliseconds. The restriction motor timer issues interrupts to the pump processor only when its timer times out. Any pending restriction motor step command is automatically executed at that time. The restriction motor timer clock period is 685 microseconds.

5.7.10 Transfer Valve Solenoid Driver

The pump processor generates the PWM waveform for the transfer valve solenoid by means of a built-in timer/comparator circuit, using port pin P4.7. The pump processor reduces the duty cycle of the waveform after initial pull-in of the solenoid, in order to minimize power consumption. The PWM motor waveform is inverted by a P-channel FED, Q3, and driven by an N-channel FED, Q31, with a transient suppression diode, CR30. The resulting drive signal is then routed to the solenoid winding. The other side of the solenoid is connected to VMAIN.

5.7.11 Temperature Controller

The pump processor monitors the air temperature inside the case with a thermistor, TH1, through A/D port pin P7.0. If the temperature exceeds a preset threshold, the pump processor turns on a cooling fan, through port pin P6.4. The fan signal is re-driven by an N-channel FED, Q12, with a transient suppression diode, CR24, and a 7.5 volt zener diode, CR19, before being routed to the fan motor. The other side of the motor is connected to VMAIN, but the zener diode limits the voltage across the motor to VMAIN minus 7.5 volts, to reduce the acoustical noise.

5.7.12 External Sensor Interface

5.7.12.1 Panel Lockout Switch

The panel lockout switch is a single pole, double throw, momentary switch, which is mounted on the main board. It is accessible to the user through a flexible membrane in the rear of the case. The state of the switch signal is monitored by the management processor, via port pin P05. The software toggles between the lockout mode and the non-lockout mode with each depression of the switch.

5.7.12.2 Door Switch

The door switch is a single pole, double throw, magnetically operated switch, which is mounted in the bezel. The switch is closed by means of a magnet in the door whenever the door is closed. The state of the switch is monitored by the management processor, via port pin P01. The switch is directly energized by the STIM signal, which can be generated by either processor via the ASIC. Therefore, the management processor can distinguish between a switch signal that is stuck low and a real closed door condition, by toggling the STIM signal.

5.7.12.3 Encoder and Restriction Valve

The position of the main motor is determined by counting pulses from an encoder wheel mounted to the motor shaft. The motor is first initialized to a known position by retracting it to its extreme limit. The pulses are generated by a photo-interrupter assembly, which detects the alternate spokes and holes in the encoder wheel. The encoder output signal remains high for approximately four main motor steps and low for approximately six main motor steps. This output, ENCODERSEN, is received by inverting schmitt trigger U2 on the main board, and then routed to both processors.

The position of the restriction valve is determined by counting restriction motor steps. The restriction valve is first initialized to a reference position (fully closed position) by moving it to the position where the restriction motor shaft makes initial contact with the spring loaded valve linkage. At this point, the output from a photo-interrupter assembly in the valve link makes a transition in logic levels: high for contact, low for no contact. This output, RESTRSEN, is received by inverting schmitt trigger U2 on the main board, and then routed to both processors.

The LEDs in both photo-interrupter assemblies are connected in series, and energized by the STIM signal generated in the ASIC. The STIM signal is re-driven by transistor Q33 and current limited with a 220 ohm resistor before being routed to the LED's.

5.7.12.4 Tube Pincher and Anti-Freeflow Clamp

The position of the tube pincher is determined by means of a photo-interrupter assembly in the tube pincher assembly. The output of the photo-interrupter is low when the tube pincher is closed, and high when it is open. This output, TUBEPINSEN, is received by inverting schmitt trigger U2 on the main board, and then routed to both processors.

The presence of the Anti-Freeflow Clamp is detected by means of a photo-interrupter in the Anti-Freeflow Clamp receptacle. The output of the photo-interrupter is high when the Anti-Freeflow Clamp is present, and low when it is not. This output, FLOCLIPSEN, is received by inverting schmitt trigger U2 on the main board, and then routed to both processors.

The LEDs in both photo-interrupters are connected in series, and energized by the STIM signal generated in the ASIC. The STIM signal is re-driven by transistor Q33 and current limited with a 1.3K ohm resistor before being routed to the LEDs.

5.7.12.5 Air-In-Line Block

Air bubbles in the line are detected by means of the air-in-line block. The air-in-line block printed circuit board contains two separate infrared LED/photosensor pairs, with current limiting LED resistors. One pair, the AIL pair, utilizes the different indices of refraction of air and liquids to detect air bubbles in the line. Its LED is energized by the AILLED signal generated in the ASIC. The AILLED signal is re-driven by transistor Q30 before being routed to the AIL board. The output of this pair, AILSEN, is received by comparator U4A and then routed to both processors. In normal operation, AILSEN is high for air and low for liquids.

Another LED/photosensor pair, the TESTAIL pair, is used to test the operation of the AIL LED and photosensor. The TESTAIL LED is positioned to emit infrared light directly onto the AIL photosensor. The AIL output signal is high when the TESTAIL LED is on. The TESTAIL LED is energized by the TESTAILLED signal generated in the ASIC and re-driven

by transistor Q29 before being routed to the AIL board. The TESTAIL photosensor is positioned to detect infrared light emitted by the AIL LED. Its output signal, AILTESTSEN, is received by comparator U4B and then routed to both processors. AILTESTSEN is high when the AIL LED is on.

5.7.13 Power

The main board circuits are powered by the external power supply, an onboard voltage regulator, an onboard power converter, the main battery, and two onboard batteries. See Table 5-4.

Table 5-4: Main Board Power Voltages

Name	Nominal Voltage	Source	Primary Use
VSUPPL	12V/16V	Main battery or power supply	Used to generate VMAIN and charge the main battery if on AC power
VBATT	12V	Main battery	Used to generate VMAIN
VMAIN	12V/16V	Generated from VSUPPLY and VBATT	For motors, solenoids, fan, onboard converters.
GROUND	GND	Power supply and main battery	Reference
VCC	5V	Power supply	For logic circuits.
VBIAS	24V	Power supply	For op amp and tube pincher FED's.
V+	8V	Generated from VMAIN, by voltage regulator VR1	For op amps.
V-	-8V	Generated from VMAIN, by power converter U24	For op amps.
VMEM	3V/5V	Generated from VCC and 3V battery BT2	For mgmt. processor RAM and TOD circuit.
VBKUP	4.8V	Generated from VSUPPLY, VBATT, VCC, and 4.8V battery BT1	For backup alarm and pwr control circuits.

5.7.13.1 VSUPPLY

When the Horizon™ is plugged into an AC outlet, the power supply generates 16 volts on the VSUPPLY line. The power supply then uses VSUPPLY to generate five volts on the VCC line and 24 volts on the VBIAS line. Therefore, when the Horizon is not plugged in, the power supply can generate five volts and 24 volts from any appropriate DC power source connected to the VSUPPLY line. The main board provides that DC source by means of an external main battery, which can be connected to VSUPPLY under software control, through two amp fuse FU2, FET Q34, and diode CR31. Since the power supply also sources 16 volts through a diode, VSUPPLY will reflect the value of the higher of the two sources: 16 volts when the Horizon is plugged in, 12 volts when it is turned on but not plugged in, and zero when it is not turned on and not plugged in.

5.7.13.2 VMAIN

All of the VSUPPLY current that is used by or distributed by the main board is measured through a series .05 ohm resistor, R37, and op amp U17A. The pump processor monitors the op amp output through A/D input P7.3. The node on the load side of the .05 ohm resistor is called VMAIN.

5.7.13.3 VBATT

The external 12 volt lead-acid battery is connected to the main board through a two amp fuse, FU2. The node on the load side of the fuse is called VBATT. The battery voltage is measured by op amp U22A, through two sense wires provided for that purpose: BATTSEN+ and BATTSEN- . The output of the op amp is monitored by the pump processor, through A/D input P7.2.

In addition to the analog measurement of VBATT, two comparator circuits are provided to monitor the condition of the battery. The LOWBATT signal is generated by comparator U26A and a 2.5 volt reference, VR2, whenever VBATT is less than 10.7 volts. LOWBATT is connected to the management processor non-maskable interrupt input, P10, and to pump processor input P3.2. The DEADBATT signal is generated by comparator U26C and voltage reference VR2 whenever VBATT is less than 10.3 volts. DEADBATT is connected to the power controller EPLD, U8.

The main board maintains the charge on the main battery by means of a UC3906 battery charger integrated circuit, U20, which is powered by VSUPPLY. The UC3906 automatically switches between three different charge states, depending on the condition of the battery: a high current bulk-charge state, a controlled overcharge state, and a precision float-charge, or standby, state. The pump processor can disable the charger, for test purposes, via FET Q16, using port pin P5.6.

5.7.13.4 V+

V+ is produced from 12 volts or 16 volts on VMAIN by an onboard 78L08 eight volt voltage regulator, VR1.

5.7.13.5 V-

-8 volts is produced from 12 volts or 16 volts on VMAIN by an onboard 1054 switched capacitor voltage converter with regulator, U24. The -8 volt regulator output is gated by FET Q32, which outputs -8 volts on the V- line. Q32 is provided to ensure that V- cannot become positive during power up.

5.7.13.6 VMEM

A three volt, 70 ma-hr, rechargeable manganese dioxide lithium battery, BT2, is provided on the main board, as a backup power source for VMEM. VMEM powers the management processor RAM, U10, and the time-of-day integrated circuit, U18. A 691 power supervisory integrated circuit, U5, connects either the five volt VCC or the three volt battery voltage to VMEM, whichever is higher. Therefore, information stored in the RAM and the time-of-day integrated circuit is maintained, even when the main board is removed from the Horizon™. The three volt battery is charged by an NPN transistor whenever VCC power is available..

5.7.13.7 VBKUP

A 4.8 volt battery pack, BT1, is provided on the main board, as a backup power source for VBKUP. The battery pack consists of four rechargeable, 1.2 volt, 100-110 ma-hr, nickel-cadmium batteries. VBKUP powers the backup alarm, the power controller EPLD, the power switch circuits, the 2.5 volt reference, and the main battery threshold detectors. Therefore, the backup alarm will be operable, even if the Horizon is not plugged in